The Blast Furnace and Steel Plant

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The Blast Furnace and Steel Plant

Vol. X PITTSBURGH, PA., MARCH, 1922 No. 3

Discussion on the Disintegration of Blast Furnace Linings

This Is a Discussion of an Article Written by P. O. Menke on This Subject and Published in the February Issue of The Blast Furnace and Steel Plant.

By RAYMOND M. HOWE[*]

THE first article on this subject appears to have been written by John Pattinson in 1876.[†] The furnace involved was 85 feet high and 27 feet in diameter at the boshes. After being in blast five years the top brick became contaminated with carbon and disintegrated. Upon examination of the lining it was found that the discolored, disintegrated brick were in a zone found from 35 to 67 feet above the hearth. Immediately below them the brick were hard and porcelain-like in appearance. This zone extended from 22 to 40 feet above the hearth. Analyses of samples taken from the different sections follow. The water-soluble portion found in the sample taken 39 feet above the hearth had a composition of approximately (See analysis 4, Table I):

Silica	.50
Lime	.04
Potash	.78
Soda	.20
Potassium chloride	6.19
Moisture	1.03
Total	8.74

The carbon deposits consisted of 84.9 per cent carbon and 15.1 per cent. ash, most of which was oxide of iron. (See Table I.)

Judging from Pattinson's statements the conditions in the furnace might be analyzed as follows:

The charge contained appreciable amounts of alkali (probably as chlorides) which volatilized in the vicinity of the bosh. These chlorides either permeated the lining in the hotter portions, condensed on the cool portions, or passed out of the furnace.

Where the temperature conditions were favorable, the chlorides behaved in the usual way and reacted with the iron to form potassium oxide, sodium oxide and volatile ferric chloride. The soda and potash then reacted with the fire-clay to form a dense porcelain-like body having a composition similar to that of true porcelain (see analysis No. V).

TABLE I.

	I. Original Lining.	II. Section 67' Above Hearth.	III. Section 45' Above Hearth.	IV. Section 39' Above Hearth.	V. Section of Vitrified Portion.
Silica	55.70	55.60	55.67	47.60	37.07
Alumina	35.50	35.40	30.00	26.47	23.18
Ferric oxide	4.00	2.67	3.00	1.32	.96
Lime	.30	.34	.23	.06	.17
Magnesia	1.21	1.22	.95	.86	.00
Potash	2.60	2.10	5.30	7.54	21.59
Soda	.45	.42	1.67	.76	6.28
Carbon	...	.05	3.24	5.97	....
Carbon dioxide	...	...	...	...	2.17
Water	...	...	...	...	7.70
Water soluble	...	...	...	8.74	...
Total	99.83	99.80	100.10	99.32	99.12

The slightly cooler lining above this was contaminated with chlorides which caused some of the iron to volatilize but which did not react to form a dense hard structure. It was in this zone that the carbon deposition was greatest (see analysis No. IV). The still cooler sections above this were not even penetrated by the alkalies.

Naturally Pattinson concluded that the skin or coat, which extended to about 40 feet above the hearth, protected this part of the lining from the various destructive influences. He also concluded that a low iron content in fire bricks is most desirable, for the carbon deposits build up about iron spots. Furthermore, he suggested the use of very hard, dense top brick as a means of duplicating the impervious coat which he believed to be so favorable to long service.

After finishing his laboratory work, he visited several other plants in order to see whether or not the condition noted by him was rare or one which had been previously overlooked. He found a distorted flue lining, a disintegrated lining, and section near a burst shell, all of which showed excessive carbon deposition at or near the point of failure.

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[*] Senior Fellow, Refractories Manufacturers' Association Fellowship, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.

[†] J. Pattinson, on carbon and other deposits from the gases of blast furnaces in Cleveland. J. Iron Steel Inst., 8, 85, 1876.

Mr. I. L. Bell discussed this paper and stated that iron causes a deposition of carbon from flue gas. Successive layers are built up from the surface of the iron and exert a tremendous disintegrating or disrupting effect upon the containers.

The chemistry of this phenomenon remained obscure for several years after Bell and Pattinson had made their findings public. In 1891, however, Messrs. Mond and Quincke prepared iron carbonyl by passing carbon monoxide over iron for a period of 6 weeks at a temperature of from 200 to 350 deg. C.[1] This combination between iron and carbon monoxide was observed to be sluggish and extremely sensitive to temperature changes. When higher or lower temperatures were involved, metallic iron, carbon and carbon dioxide were formed.

Thus the penetration of iron by carbon and the precipitation of carbon from carbon monoxide appear to be similar to the penetration of silver by oxygen and of platinum by hydrogen.

This reaction was further studied by Schenck and Zimmerman in 1905.[*] They found that the deposition of carbon from carbon monoxide did not take place in the presence of iron oxide but that the presence of iron or certain other metals was necessary. When such a metal was oxidized by CO it took place in two steps.

$$\begin{array}{lll} \mathrm{Fe} + 2\,\mathrm{CO} & \mathrm{Fe} + \mathrm{CO_2} + \mathrm{C} & \mathrm{I.} \\ \mathrm{Fe} + \mathrm{CO_2} & \mathrm{FeO} + \mathrm{CO} & \mathrm{II.} \end{array}$$

They also found that if the partial pressures of carbon monoxide and carbon dioxide in the furnace, taken together, are greater than the critical pressure, then the oxidation of iron takes place with the deposition of carbon. If the pressure is less, carbon can be deposited but no iron will be oxidized.

The critical pressure varies only with the temperature and is as follows:

500 deg. C. = 15 mm.
550 deg. C. = 35 mm.
600 deg. C. = 70 mm.
650 deg. C. = 145 mm.
750 deg. C. = 305 mm.
750 deg. C. = 535 mm.
800 deg. C. = 800 mm.

Mr. F. W. Lurmann discussed the situation in 1898.[†] He showed in detail how all refractory clays contain pyrites, which burn to form iron spots. These spots are the centers for carbon deposition, which takes place at from 300 to 400 deg. C. He had observed that fire bricks (made at the same time) remained strong when used at higher or lower temperatures, while those subjected to blast furnace service at the indicated temperatures disintegrated.

Mr. F. Firmstone described a more recent failure.[‡] In the case under consideration he found that a very good coating had protected the brick up to a height of 40 feet from the bottom, while the bricks above this disappeared entirely. An analysis of this coating, of the original brick and of the protected brick follows:

TABLE II.

	Original Brick.	Coating.	Brick 1" Inside of Coating.
Silica	55.62	40.23	57.63
Alumina	38.55	12.22	31.64
Iron oxide	4.17	11.93	3.73
Lime	.24	10.92	.24
Magnesia	.24	4.31	.11
Potash	.95	9.39	2.59
Soda	.29	8.43	.51
Zinc	....	....	1.51
Zinc oxide	....	....	.59
Total	100.06	97.43	98.55

Firmstone did not discover the presence of soluble salts in any of the remaining lining nor did he discover appreciable amounts of carbon. He did find that the bell was impregnated with carbon and that the protective coating was high in alkali. Therefore, he concluded that the conditions were duplications of those observed by Pattinson.

He stated that the furnace had been stopped several times because of the shortage of coke and that it was badly scaffolded. These scaffolds were responsible for hot and cold spots, resulting in producing a wide temperature range, part of which would favor carbon deposition.

Bernhard Osann[§] does not accept the carbon deposition theory of disintegration but intimates that this is due to the presence of alkalies.

These various opinions might be summarized as follows:

I. Iron (and possibly its oxides) will cause a precipitation of carbon from carbon monoxide at temperatures between 300 deg. and 400 deg. C. This action, although slow, may result in the building up of large carbon deposits (about relatively small centers) and in so doing disrupts the material. The necessary conditions for such deposition and subsequent disintegration prevail in blast furnace tops. Since carbon deposition has been heavy in several of the linings which failed, many authors believe that this is responsible for their failure. Furthermore, they believe that this condition is more prevalent than is generally appreciated.

II. Alkali chlorides are present in many furnaces and penetrate the lining. They then react with the iron present, forming iron chloride, which is volatile. When the temperature is sufficiently high, these chlorides combine with the lining and produce a strong, impervious, porcelain-like protective coating. This coating protects the inner lining from the action of furnace gases, the erosion of the charge and similar destructive influences.

Later publications attribute disintegration to the use of high-barium, high-sulphur ores.[¶] The zinc deposition theory is now advanced by Mr. Menke[–] and circumstantial evidence in its favor is strong indeed. It is interesting to note that Firmstone, in 1903, also reported the presence of zinc in the lining investigated by him; other investigators have reported the presence of metals which, according to Schenck, precipitate carbon.

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[1] Mond and Quincke, Note on a volatile compound of iron and carbonic oxide. Proc. Chem. Soc., 100, 117, 1891; J. Soc. Chem. Ind., 10, 644, 1891.

[*] Schenck and Zimmerman, Study of the equilibrium between Fe, FeO, C, CO and CO_2, Stahl u. Eisen, 6, 1905.

[†] F. W. Lurmann, "Destruction of Blast Furnace Linings by Carbon Separation," Stahl u. Eisen, 18, 168, 1917.

[‡] F. Firmstone, "Alteration of Fire Brick by Furnace Gases," Trans. Am. Inst. Mining Eng., 34, 437, 1903.

[§] Bernhard Osann, —, Stahl u. Eisen, 23, 823, 1903.

[¶] R. M. Howe, Blast Furnace Refractories, Bul. Am. Inst. Mining Met. Eng., 153, 5, 1920.

[–] P. O. Menke, Disintegration of Blast Furnace Linings, Blast Furnace and Steel Plant, 10, 116, 1922.

The appearance of Mr. P. O. Menke's article on blast furnace lining disintegration is particularly significant at this time. Most articles of this nature bring out the fact that the furnace was operated intermittently because of business conditions, lack of coke, or operating difficulties. In fact he mentions that banking, shoveling out or cooling aggravate disintegration which is less noticeable with continuous operation.

Various explanations are made from time to time and in a great many cases careful study reveals that they are simply attempts to attribute the failure to the refractory lining and to detract attention from operating conditions. Experienced metallurgists are content to state that the bursting of a shell is due to an abnormally high coefficient of expansion of the fire brick, forgetting that the coefficient of expansion is one of its most constant characteristics. Another explanation has been based on the assumption that the flint clay in the lining is not always properly weathered, thereby overlooking the fact that an outstanding characteristic of flint clay is that it does not weather.

One statement made by Mr. Menke appears to be worthy of more than passing consideration. He states that they investigated a lining that was apparently in perfect condition, but discovered that only the inner four inches were solid. The remainder of the lining, except one small zone next to the shell, could be crumbled in the hand. This observation has been made before and in fact was described by the writer in 1919. Is it not possible, therefore, that many of the linings in service are partially or totally disintegrated except for the inner and outer zones? This condition could easily exist in normal times without being noticed. In periods of depression, however, the operator examines his linings carefully and perhaps becomes alarmed over conditions that might not be serious. The lining described by Mr. Menke is still in service in spite of the fact that it was so badly disintegrated back of the four-inch inner face. If this inner face were to wear away would not the lime and alkalies penetrate farther, react with the brick dust, sinter the soft material into place, and thus maintain a hard inner face of this thickness? If this were not the case soft, and not hard inner faces, would be observed when used linings were examined, for the 1" face would be quickly coroded.

Returning to the discussion of facts, the writer wishes to comment upon certain points mentioned that are of particular interest to the manufacturer of blast furnace linings. Mr. Menke states that their quality has decreased during the past six years due to carelessness on the part of the workmen, that more plastic clay is now being used, that the flint clays are being ground finer, that too much stress is being placed upon producing a smooth brick of good appearance and that the resistance of different brick to zinc fumes should be studied. While he criticises the refractories manufacturer, Mr. Menke is fair in stating that disintegration cannot be due entirely to the inferior quality of the linings.

The manufacturer had no control over the care exercised by his workmen during the past few years, a fact which has been admitted. On the other hand, the workman has never been supplied with such complete information regarding his raw material as at present. If he accepts inferior clay he does so knowingly. It is doubtful, however, if this is being done to any great extent, for a recent study of some half dozen linings revealed the fact that they were of a refractoriness very close to the limit of fire-clay brick. It is also a fact that more plastic clay is not being used. On the other hand, the tendency is to decrease the plastic clay content of the more refractory brick as rapidly as the manufacturer learns how to manipulate the less plastic mixtures.

It is true that the flint clay is being ground finer, especially in the steam-pressed brick. The manufacturer, under competitive conditions, can hardly be held responsible for this tendency, however. The furnace men usually prefer a smooth, uniform brick, that is possible with finer grinding. Furthermore, the tests that are often applied by consumers distinctly favor finely ground, hard-burned, machine-made brick in every respect save spalling, which is unimportant in this service. Coarsely ground hand-made hearth and bosh brick compress 5.5 per cent in the standard load test, while finely ground steam-pressed brick of the same mix compress 3.0 per cent. In the slag test the denser brick is favored in the ratio of 15 to 1, a ratio which does not represent their relative values in service.

There is no question but what the users of refractories are exerting an enormous influence upon the quality of the product produced. If they select linings of fine grind because they are denser or smoother, manufacturers naturally meet their demands. Likewise, if the consumer devises tests which favor a dense, hard-burned, machine-made brick, the manufacturers do not hesitate to supply such a product. It is the consumer's, not the manufacturer's problem, to decide whether linings will be selected by appearance, tests, or service. There is no question, however, that many of the shorter refractory tests give results out of line with service. The manufacturer can call attention to this fact but the consumer after all controls the situation.

Mr. Menke's final statement is with respect to the study of zinc penetration. The writer can only present data as to the absorption of zinc by the retorts in which it is distilled.

Days in Service.	Per Cent of Zinc Lost Through Absorption by Retort.
1	25.79
2	23.78
3	14.37
4	8.77
5	9.24
6	6.81
7	1.70

Were it possible to prevent this absorption, it is probable that the zinc metallurgists would do so.

Editor's Note—The subject of "Disintegration of Blast Furnace Linings," has created considerable interest. We would be very glad to receive and publish any discussion which can be offered on Mr. Menke's and Mr. Howe's papers.

Recent Development In European By-Product Coking

The First of a Series of Articles Dealing with the Various Types of Electric Gas Governors Introduced in Europe—The Governor by Kress Is Described.

By A. THAU

PART II.

WHILE in former years fluctuations in the gas pressure on by-product coking plants were not taken much into account or considered unavoidable, new propositions had to be faced in this connection with the ever increasing use of coke oven gas for domestic purposes, and last but not least with the efforts to better the efficiency and heat economy of the coking plants by an ever increasing use of coken oven gas for varying purposes.

Although the design of the great majority of the apparatus forming a by-product plant has been taken from gas works practice and proportioned accordingly, different conditions altogether were responsible for the need and eventual introduction of new types of governors for which the gas works devices were not applicable.

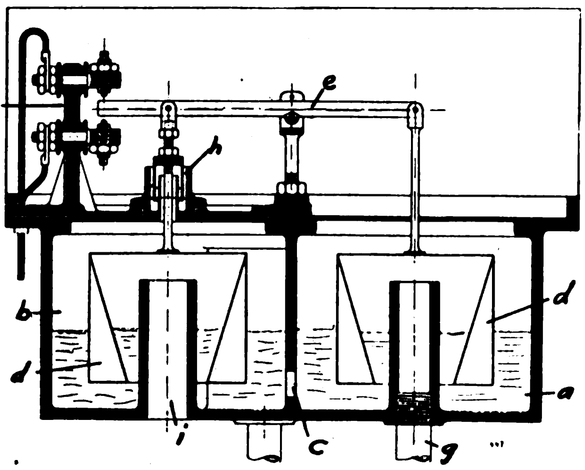

Fig. 1—Float arrangement of governor by Kress.

The usual gas works governors are working by means of a floating bell, either directly or by means of a balance lever upon a bell shaped valve cone or a butterfly valve or influencing the throttle valve in the steam main to the exhaust engine or turbine. Even though such arrangements may work very well on domestic gas plants they fail to give satisfaction if it comes to deal with huge volumes of gas at very irregular pressure and containing a high proportion of tar vapor or dust.

The need for special types of governor has been felt on coke works for two particular purposes. First, for regulating the gas exhausters so that the pressure inside the retorts remains as closely as possible near ± 0. Further need for a special type of governor made itself felt in connection with long distance gas supplies, enabling an adjustment of the pressure at will from the source of supply, i. e., the coke works, and last but not least the application of properly constructed burners to enable the gas to be burned with the utmost efficiency, requiring at the same time a steady gas flow and an even pressure.

With the great distance that is often the case between coke oven battery and gas exhausters and between the coke works and place of delivery of the gas for domestic or industrial purposes, it becomes quite evident that the gas itself is too slow a medium to convey the variations of pressure between considerable distances relative to the gas pressure.

The drawback in applying a purely mechanical operating governor to the regulating of large gas volumes rests with the fact that the distance between the receiver influenced by the variations of pressure and the valve to be moved to compensate them can only be very short because the transmitter between the receiver and the valve is either a rigidly fixed rod, in which case the variations must be corrected at the same spot where they are received, or the transmitter consists of a gas pipe taking the gas from the spot where the variations are received and conveying them to the mechanism operating the valve. One arrangement on works dealing with large volumes of gas is as unsatisfactory as the other. The former is liable to cause the valve to stick and jam with tarry or dusty gas, the latter always lags behind with its compensating movements and the more, the greater the length of the transmitter pipe line. This is due to the resistance the friction causes inside this trans-

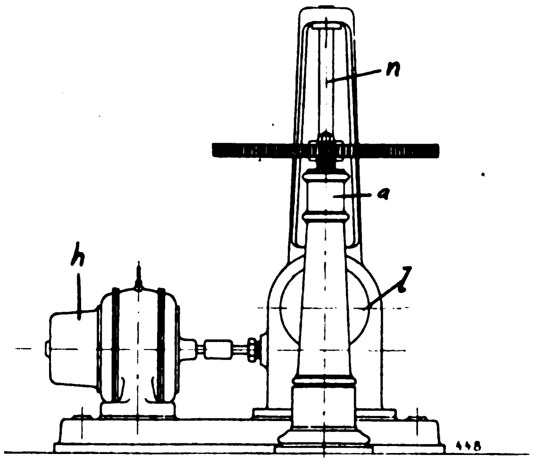

Fig. 2—Regulating valve with electric motor.

mitter pipe. The electric governors in such places fill in a serious gap in that the distance between the spot where the variations of pressure are received and the valve by which they are compensated is unlimited and has no detrimental effect upon the action by transmitting these movements over an electric cable. As the electric current transmits any movements which may be caused by variations of the gas pressure acting upon a sensitive mechanical device quite instantaneously, a perfect construction of electrically operated governors has been eagerly awaited, not only on coke works, but on all plants handling large volumes of gas, such as blast furnaces, producer plants, steel works, etc. The principal types of electric governors brought out in Europe will be briefly described in the following series.

Governor by Kress.

Kress, being a coke works manager, designed his device principally for regulating the suction of the coke ovens. The part of the apparatus directly influenced by the fluctuations of the gas pressure is shown in section in Fig. 1. It is placed near and connected to the collecting main on top of the oven battery and consists of a sheet iron case divided in two compartments, *a* and *b*. Each compartment has about one cubic foot capacity and both are connected together near the bottom by the connection *c*. In both compartments *a* and *b* a bell *d* is suspended, which are on the sides constructed as hollow annular floats. Both bells *d* are suspended loosely like two pendulums from the balance lever *e* on top. The latter projects on one end and reaches between two pretty closely set contacts *f*. The box forming the two compartments *a* and *b* is filled about half way up with water and the gas enters the compartment *a* through the pipe *g* from underneath, while the space above the water around the bell is accessible to the atmosphere. In the compartment *b* the gas enters through a side branch above the water level, affecting the bell from outside, and to prevent the gas from escaping above, the suspension rod carrying the bell is above the compartment *b* provided with cups and water seal *h*. The atmosphere reaches the interior of this bell through the passage *i* from underneath. By these means a very sensitive finely balanced device has been constructed, the effect of which can be adjusted by the variable distance between the two contacts *f* and which is the finer the closer the contacts are set apart and vice versa. A further adjustment is provided by the balance lever *e* projecting on the end opposite to the contacts and receiving a sliding counter weight which can be set to increase or reduce the senstiveness of the instrument. This attachment is not shown in Fig. 1. The cables connected to the contacts *f* are conducted to a switchboard shown in Fig. 4, provided with relays, connected to a dc. circuit and acting upon a little motor geared to the by-pass valve of the exhauster, as shown in Figs. 2 and 3 in part section right angle to each other.

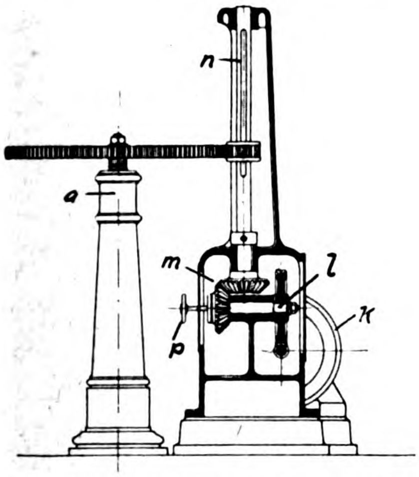

Fig. 3—Regulating valve with electric motor right angle to Fig. 2, showing wormdrive and friction arrangement.

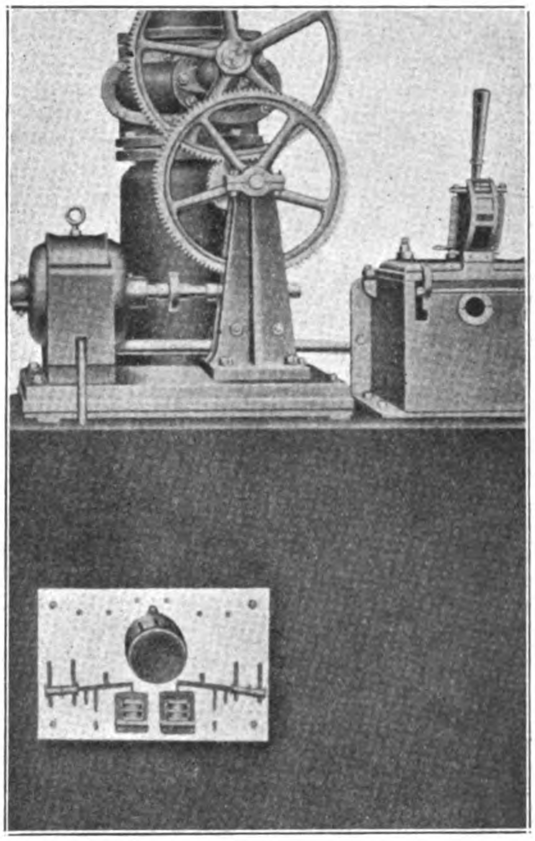

Fig. 4—Horizontal regulating valve with electric motor, also showing switch board with relays.

The motor *k* drives by means of a worm gear *l* and bevel wheels *m* the vertical shaft *n* which is keyed over its whole length and holds a sliding cog wheel, in gear with the toothed hand wheel of the regulating or by-pass valve *o*. In case of the relays sticking on the switch board and the motor not being stopped in time, there would be danger of the valve being opened or closed until something would break. To guard against this, the horizontal bevel wheel of the gear *m* is not keyed to the shaft of the worm gear, but only pressed on by a screw tightened by the little hand wheel *p*. Should thus the valve *o* be closed or opened altogether, or any undue strain be caused in moving it, the horizontal bevel wheel of the gear *m* will not turn with the worm wheel shaft and the motor can continue to run without fear of accident. On the other hand, if it is intended to throw the arrangement out of use for repairs or by a failing supply of current, the screw *p* is loosened by hand and the valve *o* can be regulated by the attendant in an instant.

While Figs. 2 and 3 show the arrangement in connection with a vertical regulating valve, it is shown in Fig. 4 in connection with a horizontal regulating valve, the gearing being only slightly different from the former. On new plants the writer found it more convenient to arrange for a regulating valve *o* with the spindle being

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screwed through the hand wheel. The latter remains then always at the same level on top of the valve column and the cog wheel on the spindle *p* can also be fixed and need not be made to slide.

The arrangement works very well, provided that the contacts on the switchboard are properly attended to, as they suffer much by sparking and scorching. The box *a* in Fig. 1 should have three or four times the depth below the bottom line of the bells than shown, so that the condensed tar can settle down on the bottom and be drawn off periodically without causing the bells to stick as is happening frequently if the box is designed as shown in Fig. 1.

A disadvantage of the last mentioned arrangement rests with the fact that the motor does not stop suddenly and runs thus often too far and is reversed again, keeping thus moving forward and backward until the gas pressure becomes stationary for a time. In all later constructions efforts have been made to overcome every movement of the regulating mechanism the moment the circuit is broken.

Babbitt—A Material For Roll Bearings

Difficulties Encountered in the Use of Babbitt as a Material for Heavy Roll Bearings and Their Remedies—General Characteristics of the Metal.

By W. S. STANDIFORD

THE use of babbitt as a material for rolls does not seem to be used to the extent that it deserves, which is due, no doubt, to a lack of information as to its merits as a bearing metal for roll and pinion bearings. In no line of manufacturing work are journals subjected to rougher usage than in the rolling of iron, steel and the non-ferrous metals as they have to withstand both heat and friction at the same time. For roll necks, brass has serious disadvantages when contrasted with babbitt ones, which are as follows: It has a great expansion when heated, thus causing the necks and end collars of rolls to be pressed together too tightly, the roll neck lubricant getting rubbed off their surfaces quickly and cutting of both metals resulting with a consequent uneven rotation of rolls and bars made differing in thickness and wavy.

It is impossible in rolling mill work to keep all journals from getting heated up to a certain extent, despite the streams of water played upon them, as the material rolled requires to be made into desired shapes while it is hot and plastic, the heat naturally extending from rolls body to their journals. Babbitt, having altogether different characteristics from brass, proves to be a very suitable metal for use in rolling mills, its advantages being of so great a value as compared with brass that it gives the utmost satisfaction when used in mills, due to its great antifrictional qualities as it is of a more greasy nature, this quality allowing it to run much cooler than brass and other metals. As babbitt can be melted in iron ladles over any fire, great rapidity in replacing worn bearings in machinery breakdowns is a most desirable and valuable feature, and also a money saver. In addition, oil grooves can be easily and quickly cut, or if preferred, cast ready made by the workmen using asbestos cord. Uniform bearings are easily obtained in casting when care is used. Babbitt also has the advantage that by use of a portable forge for heating, all work can be done on the spot near the rolls, engines or other machinery, thus saving time by eliminating walking of the workers to and from the job to the lowest possible extent.

This metal deadens noise, and last, but not least, is cheaper than brass. There are a variety of different grades of babbitt on the market adapted for various machine requirements, such as high pressure and fast speed journals, medium pressure and high speed, medium pressure and medium speed and also low pressure and medium speed. High pressure and fast speed metals generally contain more tin and antimony and also a small amount of copper, while the low pressure and medium speed metals have smaller quantities of tin and antimony and also a large amount of lead. Tin, antimony and copper confer hardness to babbitt, so it will readily be seen that those who prefer to make their own metal in various classes of their own machinery bearings can easily regulate its hardness. There are many varieties of babbitt on the market so that any manufacturer who desires to purchase this metal will have no difficulty in selecting a suitable grade for his machines. Personally, the writer thinks that, except for a few special cases, two kinds, one a lead base alloy and the other a tin base one, are sufficient for the average class of machine journals, rolls included. But each metal should be of the highest grade that can be made. Rarely are bearings made entirely out of solid babbitt, except some very small ones, including those made by using die-cast machines; these latter are cast complete with oil grooves in them. They need only to be turned and faced off before using. In general use, babbitt is used only as a lining in bearing shells of cast iron, malleable iron and bronze.

Steel castings were found out by experience to be unsuitable for this purpose on account of warping tendencies when casting strains are removed by machining. Cast iron shells on account of their cheapness and great strength are most commonly used for stationary machines, some malleable ones being in use for the same purposes. This class of shells comes in handy for rolling mills where heavy vibrations are encountered in the rolling processes. The railroads mostly make extensive use of bronze shells so as to insure the completion of their runs. Bronze shells with a babbitt lining are also made use of extensively in the automobile trade.

From the foregoing facts it will readily be seen the esteem in which this metal is held as a bearing metal in various manufacturing lines. Owing to the different set of conditions met with in which roll and pinion journals operate, such as heat and friction, it is necessary to use a babbitt of such a composition as will prove suitable for the work. The formula given below is one that has been found out by long experience to give good satisfaction, it being one that enables the rolls to continue in action for long perods of time until the bearings need replacing.

Formula for Roll and Pinion Babbitt Metal.

1400 lbs. lead
232 lbs. antimony
165 lbs. alloy (tin and antimony mixture)
5 lbs. bismuth

In making up this formula, there is needed a cast iron pot and also some ladles of various sizes; the latter should be of the self-skimming type, having a welded bridge across the spots so as to prevent dirt and dross from getting poured in with the babbitt. The iron bridge also prevents splashing and enables a good sized stream to be poured. A supply of mandrels, clamps, etc., will also be required by the machinists' or millwrights' repair forces. In making up the formula given, experience shows that it is best to melt and mix the tin and antimony alloy separately from the other ingredients. This is due to the fact of its taking a greater degree of heat to melt them than lead, as it is a matter of importance in melting babbitt (whether it is purchased ready for use or made on the premises) to avoid burning, as the latter produces heavy shrinkage in the lining shells besides reducing its antifrictional qualities.

It is also rendered softer and dirty in texture, all burned bearings wearing out rapidly. Place the tin and all of the antimony, also bismuth, in a crucible; heat until melted. Heat lead separately in cast iron pot until it is fluid, then add the alloy mixture to the lead, stirring vigorously to make a uniform metal and allow the pot to remain on the fire for a while so as to make sure every ingredient is thoroughly melted and mixed, the amount of time depending upon the bulk of metal made. Powdered charcoal or sawdust should be kept on its top surface to prevent oxidation and formation of dross by the air. If it is desired to have a supply of babbitt bars for stock room, use channel irons as a mold, spacing it off into desired lengths by means of short pieces of boards put crosswise in the channel, short sections of suitable sizes as will fit into the melting pot and weighing 50 lbs. apiece will prove a very desirable weight for stockroom shelves.

Channels make very desirable molds for casting ingots of bearing metals, as their weight can be controlled by using channels of varying widths. If it is wanted for general use, leave it in the pot until needed. In rolling mills there are two different types of bearing shells used with cast iron retaining walls to give the desired strength and rigidity, viz: Those that are cast in a solid piece, and also others which are made in two piece sections. The one-piece ones are cast on smaller diameter mandrels having a 1/16-inch taper so as to facilitate their removal when the metal is cold, the babbitt being afterward bored out on a boring mill to such a diameter as will make a neat sliding fit. This style of bearing gives good service on mill pinions, it even being used also on blooming mill rolls.

To give an idea of the amount of babbitt required in large pinion bearings, each one will need 1,200 lbs. of babbitt. The grease slots are cast in them so as to save work. In casting such large and heavy bearings, care has to be taken to put a weight and also clamps around the box and over the mandrel, as the weight of metal pressing against the retaining boards is likely to burst any mold apart if they don't have sufficient strength to resist the hot babbitt's pressure. Air and pouring holes should also be provided so as to get sound castings free from blowholes. The making and handling of babbitt is a very dangerous task, great care having to be taken that no dampness or water should be around while the pouring is being done, as it will explode with disastrous results to workmen around it.

The main drawback in casting large roll and pinion bearings exists in the time taken to cool them so that they will stand handling, but this can be overcome by having four mandrels of the same size for each set of heavy rolls and pouring them one after another. Much work can also be saved by filleting out the mandrels, the former to contain the same radius as those on the rolls. It is also a good plan to have a supply of the finished bearings in the stockroom, as they come handy in emergency breakdowns which at some time or other occur in the best of mills. Blooming mill top roll bearings and other large movable roll bearings in which the wear is extra heavy due to the jerk of rolls when an ingot enters a pass usually have a narrow brass liner with the same radius as the roll necks cast in with the babbitt, the latter metal surrounding and holding it in place. This combination enables all bearings of such rolls to resist wear at their most vulnerable spots. The same result can be achieved by adding a much larger percentage of tin and antimony and also some copper to the babbitt, a reduction or an entire elimination of the lead tending to give hardness.

Increasing the amount of tin and antimony also increases the cost of bearings, especially large, heavy ones. One and two piece shells usually have their linings held in place (to prevent its rotating with roll necks or shaft journals) by means of dovetail grooves, or round anchor studs—sometimes both are in use in cases of heavy rolls weighing 8,000 lbs. or more. The extensive employment of electric dynamos and motors in modern rolling mills calls for a special high grade babbitt in order to make them give the least amount of trouble, day in and day out. These machines are in operation continuously 24 hours so that their bearings get no chance to cool off; in addition, they run in a very hot atmosphere containing a dust composed of very small particles of iron. The latter is produced by the rubbing contact between the rolls surface and metal rolled. For use in such machines, a special babbitt formula is appended, which has been found by years of experience to give excellent results.

Special Babbitt Formula for Electric Dynamos and Motors.

438 lbs. tin
40 lbs. antimony
27 lbs. copper

The above metal is well suited to the high speed and heavy pressures exerted on armature shaft bearings by light and heavy mill motors. As the latter usually have their shafts oiled by revolving rings, these shells for mill motors can be made out of cast iron, although bronze can be employed for this purpose if desired. The cast iron ones are best, owing to the rapidity in which they can be relined as contrasted with those of bronze.

All motor bearings ought to be poured on a much smaller mandrel, the latter having a 1/16-inch taper so as to facilitate ease of withdrawal. They should then be bored out carefully to the desired size. Extreme care must be taken by the workmen to see that no dirt, dross or iron scale from a very rusty ladle gets into this metal while pouring shells, as they will run hot and start to cut both shaft and babbitt, the latter melting in spite of the oil rings conveying oil to them. When the babbitt is worn down in shells, all old metal can quickly be removed from them by first carefully cleaning them from oil and dirt of all kinds and then placing them in a pot of melted babbitt, thus melting it out. By adding old metal (providing that it has not been burnt) to the new, expense can be saved in this direction, as such material will be found to be most useful and again give good service.

Babbitt for motors and dynamos should be kept in a separate place from that used on the rolls, so as to avoid mistakes made by careless workmen using the wrong metal. Another place where this special motor babbitt can be used to great advantage as regards the quickness in which repairs can be made on emergency jobs as well as excellent results obtained in regular work is as a bearing lining for crosshead slides on steam engines, this metal to replace the usual brass ones, the latter requiring a lot of machine work to be done upon them before they are ready for use. The babbitt ones need less work in that respect, thus enabling the machine to be gotten into operation quicker. The proper lubrication of all bearings, whether they are roll necks or engine slides, seems not to be so well understood by the average run of mill superintendents as might be the case, as many seem to think that all that is necessary is to supply machines with grease or oil and let it go at that, the men accepting all wear on journals as an evil which cannot be avoided.

It is true that wear on any bearing and journal cannot be prevented, but it is also true that it can be minimized to the lowest possible extent by using the right type of lubricant for differing sets of working conditions among various classes of machinery. Proper lubrication of roll necks is one of the most difficult propositions encountered, which is due to the heat imparted to the bearings during rolling of the hot metal and also to their tightness, that the roller is forced to keep in order to retain the desired sizes while the mill is in operation. It will readily be seen from the foregoing that not only is a lubricant "scraped off by brass bearings, but that excessive pressure is exerted against both necks and roll end collars by the heavy expansion of the heated brass." As a general rule, it will be found by experience that babbitt lined shells will enable all rolls to keep in better shape and last longer before being relegated to the scrap heap, all babbitt metal working better with any of the usual roll lubricants than brass, as babbitt is of itself a much more greasy feeling metal.

The regular lubricant in use on most roll necks is suet, which is obtained from butcher shops, pieces of the material being laid upon roll necks, the heat of the latter melting some of it, which combines to a certain extent with the running water, the latter carrying this greasy mixture between bearing surfaces. Such a mixture has the characteristics of a very thin oil that runs off hot surfaces rapidly and prevents wear to a certain extent. It is well known among lubrication experts, but not by the average run of mill and factory officials, that the consistency of any grease or oil has to be suitable to the weight and rapidity of motion of different machine parts, a lightly constructed machine such as a watch requiring a very thin oil to enable it to run. On the other hand, a thin oil proves to be unsatisfactory for roll and pinion necks, as it is squeezed out by their weight before it can get in efficient work. The suet and water mixture is like a thin oil, it being very costly in the end as regards the length of time that rolls can be operated before they are thrown away in the scrap heap.

Graphite works on an entirely different principle from oil, and it is the best lubricant of all for heavy machinery in rolling mills. To those not acquainted with the properties of graphite and the way that this substance prevents friction, a few pointers about its lubricating qualities will be of interest. The theory and practice of lubrication is to keep two surfaces apart and prevent, as much as possible, their rubbing together, as metals are never smooth. Viewed under a powerful microscope, the most highly polished pieces of metal resemble a nutmeg grater; there are many pin points sticking up, with all pores in metal, tool marks and other irregularities that taken altogether help to produce friction. When the oil on a bearing squeezes out, these irregularities and pin points interlock, with pin points breaking off; this is termed wear. Tiny particles of metal are then carried by the oil into the bearing parts, thus acting as an abrasive. The use of graphite grease containing a large percentage of graphite entirely overcomes this state of affairs.

The graphite first fills up all pores of the metal by being rubbed into them, after which a veneer of graphite is thus placed over the entire wearing surfaces. After this veener of graphite has been obtained, all friction will have been reduced to the lowest possible extent known to mechanics. Another factor that helps to prevent undue wear on the bearings is that the latter, having become coated with graphite as is also the journal, contact is now between graphite and graphite and not metal and metal. It is obvious in this case that all wear is reduced to a minimum. To show the effects of graphite in reducing friction, the following test is instructive. Take two small pieces of paper and lay one upon the other, then try to move the top one over the bottom paper by applying weight and force. It will be found that friction is holding both sections of paper together. Now take some fine flake graphite and rub a little thoroughly into the pores on both sheets of paper, placing the two surfaces together and move them the same as before. You will now find that both sections will move easily one upon the other, and also find out the fact that the more weight you apply, or in other words the more work that the graphite is given to do, the easier both parts move. Unlike oil, graphite cannot be squeezed out under any circumstances, but it remains at all points of contact. This test illustrates the truth that, irrespective of weight, a film of graphite cannot be squeezed out by any pressure, no matter how great the force exerted. In fact, the more weight that is applied the firmer the graphite becomes embedded in all metal pores, the result being that the latter's surfaces are made very smooth. As babbitt is by nature a more greasy substance when compared to brass, the use on roll necks of a graphite grease comes about as near to an ideal mixture as can be expected considering the conditions under which the rolls are worked as regards both heat and friction at the same time.

In respect to the actual work of babbitting boxes, the greatest care in handling this metal should be taken by the machinists' or millwrights' gang so as to get the best possible results, as any carelessness in handling it not only injures a babbitt's quality, but causes the poured bearings to wear out very rapidly and thus makes renewal necessary with its additional expense and loss of time that could be put to better advantage in doing other work by the maintenance forces of mills and factories, as it often occurs that these men have two or more urgent jobs which need attention at the same time.

Another factor in babbitting work is due to the readiness in which the average run of workmen "lay the blame upon a metal's quality," it being said "to be inferior" when, as a matter of fact, the fault is entirely with the workmen and their methods of handling, as the finest quality of metal ever produced can be made to appear as if it were of a cheaper grade and worthless. Mill foremen being, as a general rule, very busy persons, have to depend to a large extent upon what their employes say about a babbitt's quality, they not knowing all the conditions under which it was heated and poured. For the information of this class of men as well as for their workmen who in the vast majority of cases are very fair minded and desire to do effective work and only put the blame upon the metal's quality because of sheer ignorance, this list of the difficulties encountered and the proper remedies to overcome them are appended, which will no doubt also be of interest to all classes of mill and factory men, as a better understanding of bearing metals will be of great advantage to the keeping of machines in action so as to give the least trouble.

Difficulties and Remedies in Babbitting Work.

Difficulty—Blisters on solid one-piece and also two-part bearings.

Remedy—These blisters are caused by a workman putting oil on the mandrel so as to prevent the latter from sticking to the finished casting. They occur mostly on one-piece castings, although the two-part ones will show this defect if oil is used. Their size varies with the amount of oil put on and its viscosity. Rub flake graphite over mandrel's surface that is in contact with hot metal and stop using oil for this purpose. If no graphite is handy, use a very thin coating of white lead and let dry before use. Two-part shells, in most cases, will not need any graphite or white lead on mandrel, as the latter can be easily removed when castings are cold enough to handle. Mandrels should not be taken out of contact with castings while they are hot, as warping and hollow cavities will be the result of such treatment.

Difficulty—High grade babbitt casting has large numbers of hard and soft spots and it has a dirty looking casted surface.

Remedy—Cold babbitt has been solidified in the melting pot and was reheated too rapidly by the workmen trying to hurry along the work. The lighter metals in its composition rise to the surface and become oxidized by their contact with the air, while the heavier ones sink to the bottom. Pouring under the above conditions makes a series of hard and soft spots. Slower heating and more stirring and the use of a layer of charcoal or sawdust on top of the molten mass will produce a uniform casting.

Difficulty—Extreme shrinkage of high grade babbitt castings in bearing shells resulting in a loose bearing; broken anchors and porous areas. This metal will also be found to be oxidized, softened and dirty, and its anti-frictional qualities destroyed.

Remedy—The above is one of the cases in which the employes put the blame on the babbitt's being of an inferior grade instead of their own fault in handling. This condition of metal is due to the fact that it was heated and poured at too high a temperature. thus burning and oxidizing some of the more fusible metals. Careful attention to the proper melting point and also to the mandrels and shells temperature along with the use of charcoal on babbitt's surface will obviate this trouble. All babbitt metals of the various grades on the market ought to be heated to such a temperature so that it will just char a pine stick when it is plunged into it and instantly removed. This is a rough and ready shop method, but it is effective just the same.

The proper temperature of a mandrel is also shown to be just right when a drop of water will evaporate quickly from its surface without sputtering, the heat of the mandrel being that of boiling water. Never allow any babbitt of whatever grade used in the mill to get red hot in its melting pot, as it will be ruined. Some workmen when doing work among crowded lines of factory machines locate their fire too far away from the place of work and then purposely overheat the babbitt in ladle and run with it to the machine, expecting it to have the right temperature for pouring and making good castings when they get there. This is bad practice, as it causes the finished work to contain all of the above enumerated defects. The proper thing to do in cases of this kind is to shut down the machine that is next to the one requiring babbitting, then bring the portable forge used in heating the metal as close to the machine as possible so as to avoid burning the babbitt.

For field work of this character it is much better to use a tin base alloy, as it is a metal that is much better suited for field work than a lead base on account of its capability to withstand much more abuse than the lead base material.

Difficulty—The lining has a coarse granular structure looking as if sand had been added to it when melted.

Remedy—The coarse granular structure is due to the babbitt having been heated and poured into lining shells at too low a temperature. The latter should be just right for good results. The too low heating of babbitt is mostly done by "workmen who watch the clock" and wish to quit when the whistle blows, although it occasionally happens through carelessness of workmen desiring to get the work done quickly.

Difficulty—Numerous blowholes in linings, the latter shrinking away from the shells when the metal is cold.

Remedy—This is a case in which the heat of the melted babbitt is correct, but the shells and mandrel are too cold. Proper heating of both shells and mandrel will cure this defect. If the blowholes are still numerous after applying the above remedy, have more air-vents when pouring the hot metal. A lack of enough air-vents will cause the babbitt to bubble and prevent all air from escaping from the hot metal.

Difficulty—Linings soft at tops and brittle at their bottoms, thus wearing unevenly.

Remedy—Shells and mandrel are too hot, the result being that the hot metal is made to cool too slowly, thus allowing the heavier metals to sink to the bottom of lining while the lighter ones remain on top. Proper attention to heating and the other details will remedy this state of affairs.

Difficulty—Spongy and dirty looking castings when metal and mandrel, also shells, are of right temperature.

Remedy—Too much dross was allowed to get into the melted babbitt while pouring. Workmen should always dip the ladle from the bottom of the pot so as to avoid getting too much of the surface layer of metal in pot. Use a self-skimming ladle having a spout so shaped as to pour a round, thick stream instead of a wide, flat one. Such a ladle will prevent, to a large extent, the castings from being spongy and dirty. A broad, thick stream which is poured intermittently and slowly will also produce porous areas and blowholes, the air oxidizing the babbitt's surface. The latter ought to be poured in an even steady stream without surging in ladle, as surging forces dross into the castings. Spongy and dirty castings are also produced by workers throwing too many small pieces of solder in the babbitt melting pot. All small pieces of solder should be saved for future use in soldering and be remelted and made into long sticks, an angle iron mold making a very desirable stick; the lengths of stick can be controlled by clay spacing angle iron into sections.

Difficulty—Too much shrinkage in shells when using a low grade babbitt, temperature of metal, lining shells and mandrel being just right.

Remedy—If much low grade metal is used as a lining, it is best to employ a much smaller diameter mandrel, then take a round-faced hammer and, starting in the center of casting, tap it lightly along its center, extending the blows gradually up both right and left hand sides until the top is reached.

This hammering process spreads the metal sufficiently so as to make it fit the lining shells. Next, bore in a boring mill or scrape them to size. This method, though effective, is not recommended for continuous use, as it wastes too much time and money, but it will do for emergencies when breakdowns occur and a factory is caught without a supply of a higher grade metal which obviates this trouble.

Difficulty—Small two-part split bearings made out of a lead base babbitt have a spongy surface on shaft bearing part. Heating of shells, mandrel and babbitt being correct.

Remedy—This is due to the fact that the shells have been poured with the mandrel on top, thus allowing a certain amount of dross to fill up the part of shell in contact with the shaft; a lead base alloy generally has more dross to it than a tin base one. These small two-part bearings are best poured in a horizontal position, bottom upwards, in the bottom of shell. This method of working has the advantage of making the bearing surface next to mandrel very clean and dense, any impurities or dross being on bottom parts of shells.

In the pouring of large two-part bearings using the same quality of lead base alloy as the small bearings listed above, it is much better practice, in order to get sound castings, to have the shell and mandrel in a vertical position, the front bearing surface facing downwards. This causes any dross that may form to rise to the back end of casting. These large bearings may also be cast bottom upwards like the small two-part ones, but it will be found much more convenient to do the pouring with shells in a vertical position.

Difficulty—Babbitt will not stick to bronze linings of electric motor shells, mandrel hot, metal, shells and temperature being right.

Remedy—The part of the shells where the babbitt touches them ought to be tinned with a thin film of half and half tinners' solder, using a flux of chloride of zinc. The hot babbitt coming into contact with solder surface will melt the film and effect a conjunction between the two metals. Under no circumstances should the soldering flux be added directly to the hot babbitt, as it doesn't work well with it and causes trouble

Difficulty—Workmen trying to make babbitt stick directly to iron shells by tinning the latter, everything being at right temperature.

Remedy—The sticking together of cast iron shells and babbitt cannot be depended upon, as these metals do not alloy at molten solder temperature, it not adhering to shells when both are cold. Should a higher heating of babbitt be tried to effect a junction, the solder will be oxidized and the babbitt's quality ruined, no adherence between iron and babbitt taking place.

Difficulty—A lead base alloy refuses to give satisfactory service on factory machines, with hot metal and shell heat being correct.

Remedy—It is evident from the above state of affairs that too much vibration of moving parts is the cause of rapid wear, a lead base alloy proving much too soft a metal for use on such machines. A tin base alloy containing a higher percentage of tin and antimony will work well, preventing trouble of this kind.

Difficulty—A high grade babbitt wears unevenly and is very brittle, crumbling like granulated sugar in spots.

Remedy—Workmen having burnt overheated babbitt in ladle have attempted to restore the quality by adding new metal to it. Such a mixture should be thrown away as it cannot be restored Care ought always be observed in the heating and handling so as to avoid such a waste of money. Quick and rapid methods of doing repair work is the rule nowadays, and any process that helps to reduce the time taken in getting various classes of machines in operation meets with a warm welcome by all classes of employers, as breakdowns will occur at the most unexpected times. There are also many repair jobs on small machines which, on account of wear on their bearings, require to be done over again at intervals, the rebabbitting of boxes on small engines, nail machinery, etc., being among them. After having had a number of rebabbitting of crankshaft shells that were lined up in the usual slow manner, the writer devised this simple and rapid style of leveling their shafts, it having been used on numerous occasions with good results as regards the working of the finished machine.

The sketch (an end view of shaft and one box) shows clearly how this leveling is done. Drill two holes opposite each other in both boxes to fit small brass machine screws, place shaft in position, using a level to get it straight, turning screws in or out to get it level. The usual methods adopted by workmen to prevent molten metal from running out bearing ends should then be taken. Turning screws as needed enables quick work to be done. The shaft may be removed for warming and put back on tops of screws with the certainty of its being level. These brass screws ough to be left in altogether after pouring of metal as they prevent the threads in cast iron shells from getting filled up with babbitt, thus making rapid work in replacing new bearings when old ones are worn. These screws are easily removed when bearings are worn, as new ones will have to be inserted into the threads for each rebabbitting job.

I will now close by giving another fine electric motor lead base bearing metal formula which will run well in an atmosphere of 90 or 100 deg. F. and give the least amount of trouble. This babbitt is made out of a mixture of lead and antimony combined with a small amount of tin. Lead and antimony are metals that have a chemical affinity for each other, which property causes them to combine in all proportions without any impairment of the antifrictional qualities of either. The antimony also confers hardness to the lead, thus enabling it to stand a higher rate of speed in a rolling mill temperature without abrasions and heatings of the linings taking place, provided that care has been taken by workmen in pouring metal, etc., and dirt is kept out of all bearings during operation of the machine.

Babbitt Bearing Formula for Electric Motor Operation in a 100 deg. F. Atmosphere.

450 lbs.	lead
150 lbs.	antimony
6 lbs.	tin

It must not be inferred from the foregoing that the above babbitt is only suitable as a bearing lining for machines working in a warm temperature. As a matter of fact, it will be found to be of great service for motors and dynamos running in ordinary locations. Should any additional toughness be desired, the tin can be replaced with an equal amount of copper, although it will be found that this metal is sufficiently tough to give good results without any addition of copper.

In judging the quality of babbitt, whether it is bought ready made or manufactured on the premises, a good shop way of sizing up its excellence or otherwise, as the case may be, is to examine a bar's fracture when broken. First-class metal should show a fibrous fracture, having no white oxide patches. If any babbitt on fracture contains such patches, it denotes that it has been poorly made and worthless in regard to giving good service in bearings. As a general rule a babbitt with a large tin content will show a lighter surface when broken, as contrasted with a lead base one. All babbitts will streak paper more or less, if they are pressed hard enough upon it; however, the ones that contain much lead will make the blackest marks.

Some mechanics add phosphorous to the babbitt with the idea that it will cause this metal to adhere better to iron shells. Phosphorous has the above effect, but it also has the drawback of causing it to flow very sluggish when pouring and makes the casting full of blowholes. On this account, phosphorous ought not to be added to babbitt, or if used at all, very sparingly. When the rules for doing babbitting work as given in this article are followed, neat and clean castings will be the result, regardless of the grade of metal used.

Electric Motors in the Steel Plant

Electric Motor Breaking as Applied in a Steel Plant to Restrict Speed of Overhauling Load, to Cause Definite Slow Down and to Stop.

By **GORDON FOX***

PART I.

THE electric motor may be employed not only to accelerate and drive machinery, but also to decelerate and stop it. A distinction may be drawn between three types of braking. In lowering an unbalanced load as with a crane or a mine hoist, the motor merely restricts the speed and retains the overhauling load within bounds. In an elevator drive or a skip hoist drive the motor often serves to reduce the speed from full running value to a lower definite value as the end of the travel is approached. With some machine tools and in many steel mill applications, the screw down for instance, motor braking is used to bring the motor to a stop. Motor braking may thus be used:

1—To restrict speed of overhauling load.
2—To cause definite slow down.
3—To stop.

Braking may be accomplished, with a motor drive, either by the motor itself or by an external brake. The motor acts by torque electrically developed in a direction opposing the motion. The brake acts mechanically through friction.

The direction of rotation of a direct current motor is reversed by reversing armature connections. The rotation of an induction motor is reversed by interchanging primary phase leads. If armature or phase leads be reversed while the motor is running, the motor will develop torque opposing rotation, bring the rotor to a stop and start it in the reverse direction. This procedure is termed "plugging" a motor.

If a direct current shunt motor be driven above normal speed it will revert into a generator and will tend to deliver power to the electric system. It therefore requires mechanical power for its drive and acts as a drag. In like manner, an induction motor driven above synchronous speed becomes an induction generator, delivering electric power and demanding mechanical propulsion. Braking by the above methods, in which electric power is returned to the electric system, is commonly termed regenerative braking.

If a direct current motor, while running, have its armature disconnected from the line and then short circuited through a resistance, with the field excited, the motor acts as a generator and circulates current through the armature and the resistance. The energy absorbed in the resistance of the armature and its external circuit is translated from mechanical energy by the motor. Braking by this and similar means wherein the motor is converted into a generator dissipating energy in external resistance, is commonly termed dynamic braking.

Having outlined the various methods of motor braking, we will consider a little more in detail the nature of their action. When a direct current motor is running, it generates a countervoltage which opposes and nearly equals line voltage. When the motor is plugged, the countervoltage continues in its previous direction so long as rotation continues. The impressed voltage is reversed by reversal of armature leads. The impressed volts and countervolts are therefore temporarily additive.

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The voltage existing momentarily across the armature and starting resistance in series may therefore be nearly twice line voltage. As the motor slows down, prior to reversal, the countervoltage decreases and lowers this total voltage. It should be evident that, to restrict the armature current at the instant of plugging, a series resistance materially higher than starting resistance, is required. Plugging is often mentioned as a deplorable practice. This is true in the case of control which is designed for starting duty only and which does not provide sufficient series resistance to restrict the plugging current peak to a safe value. It is also true if the series resistance, although suitably provided for plugging, is cut out too rapidly. Plugging as practiced with suitable plugging resistance added to the starting resistance and with features preventing too rapid short circuiting of this resistance, is an entirely commendable practice. A disadvantage of plugging lies in the fact that the motor is not only stopped, but reversed. If it is desired to merely stop the motor it is necessary to cut off the current at exactly the right instant either manually or by a relay or governor. An advantage of plugging lies in the fact that a strong decelerating torque is maintained by the motor down to and through the point of reversal. It may be remarked that the proper value of total series resistance, inclusive of starting and plugging resistance, may be ordinarily approximated by dividing 150 to 175 percent of line voltage by the permissible current peak. Line voltage plus countervoltage usually totals 150 to 175 per cent line voltage, momentarily. It may be noted that if a series motor is plugged from a high speed, the combination of high speed and strengthened field caused by the increased plugging current will greatly increase the countervoltage and consequently increase the momentary voltage peak and plugging current inrush. For such cases a higher plugging resistance is required. This is apparent from the curves shown in Fig. 1 showing speed current characteristic of a series motor with various values of series resistance. The values below the zero line show the plugging current at any speed with the amount of series resistance as shown. Incidentally, it may be remarked that an adjustable speed motor should not be plugged on a weak field. If plugged from high speed, an extreme plugging voltage and current peak will result.

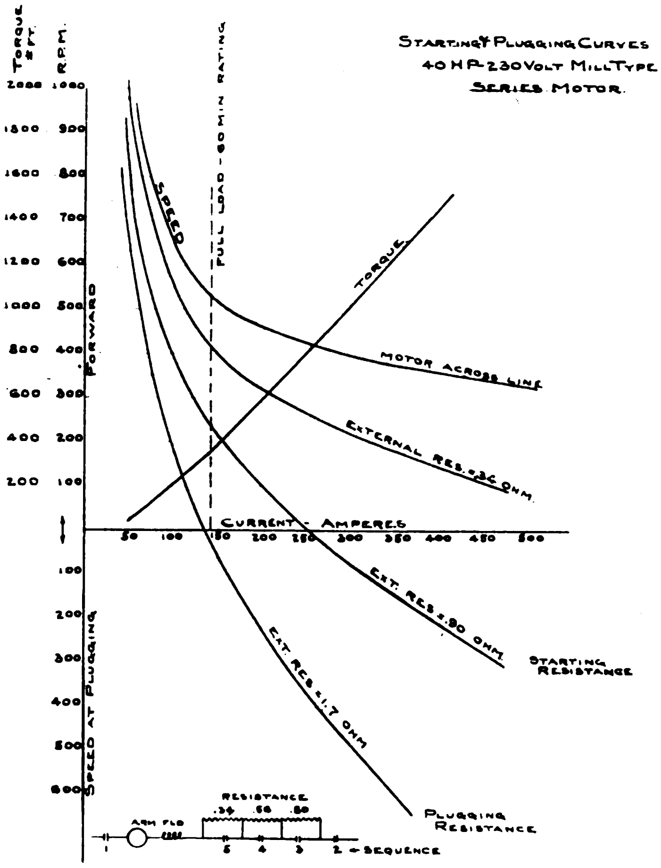


Fig. 1.

The plugging of induction motors is a less frequent practice as they are less commonly used for drives requiring manipulation. The squirrel cage motor draws a high current peak when starting from rest. It will draw a still higher peak if plugged. The high resistance cage motor may be adapted for plugging duty. The wound rotor motor may be and is quite commonly arranged for plugging. In order to restrict the plugging current peak, extra secondary resistance is required just as in the case of the direct current motor. It should also be noted that the voltage and frequency in the rotor circuit are nearly double the values existing when starting from rest. If a wound rotor motor is to be plugged it may require special insulation of the rotor windings and extra clearances at the collector rings and brushes. The same general conditions governing plugging practice apply in the case of both alternating and direct current motors.

All that is necessary to convert a direct current motor to generator action is to increase the speed or strengthen the field to such a point that the countervoltage generated is greater than impressed voltage. Fig. 2 shows the speed load curve of a motor from which it may be seen that a slight increase above no load speed will cause generator action. This applies in the case of a shunt wound motor. A compound motor has a steeper characteristic so that a greater increase in speed is necessary to cause an appreciable generator load. If a compound wound motor is used in connection with overhauling load the series field is generally cut out during running intervals, to give a shunt characteristic. A series motor cannot be employed as such in this capacity as the load cannot be removed without causing excessive speed. A shunt characteristic is necessary to obtain regenerative action without wide speed change.

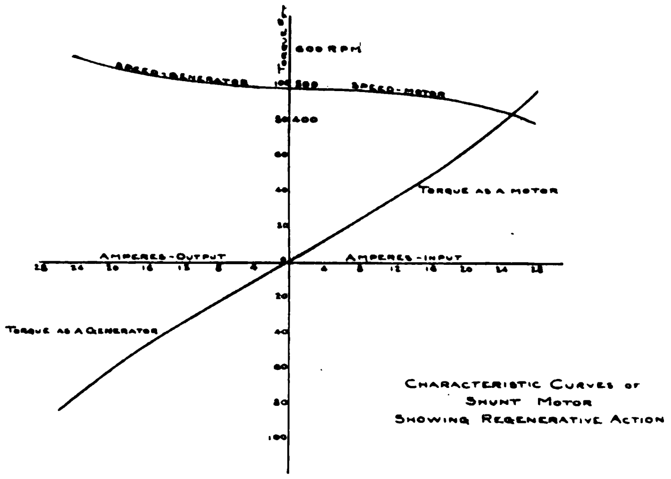
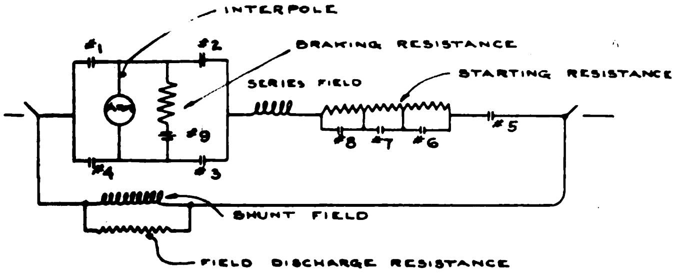


Fig. 2.

An induction motor, driven above synchronous speed, becomes an induction generator. The amount of speed change necessary to produce an appreciable load change depends upon the motor characteristic. A squirrel cage motor with a flat speed load curve will change from motor to generator action with a relatively small speed increase. A high resistance cage motor or a wound rotor motor with external resistance in circuit will not produce effective generator action except as a result of a considerable speed increase. This is of particular interest in connection with electric elevators where a flat characteristic is desirable for regenerative braking, but where considerable secondary resistance is necessary to produce the desired starting torque.

Dynamic braking is employed for restraining, for slowing down and for stopping. These applications will be considered in reverse order. To stop a motor by dynamic braking, the armature is disconnected from the line and then short circuited through resistance. The braking current is proportional to the voltage generated in the armature. This, in turn, is proportional to the speed and the field flux. The current is also inversely proportional to the resistance of the armature and external circuit. The braking torque is proportional to the armature current and the field strength. Dynamic braking can be quite readily accomplished with a shunt or compound wound motor, the braking field being supplied by the shunt winding. Fig. 3 shows the principle connections of a reversing control for a compound wound motor, with dynamic braking used for stopping. Note that the series field should be omitted from the braking circuit, but the interpole should be included in the circuit. In the case of the adjustable speed motor care must be exercised not to brake rapidly from a weak field and high speed. If the field is rapidly strengthened at the same instant that the armature is shorted through the braking resistance, excessive voltage and current will obviously result. This occurrence is prevented in some magnetic controllers by a relay which prevents strengthening the field faster than the braking current flow permits. To obtain effective dynamic braking on a compound wound motor a liberal shunt field winding is necessary to supply a stiff field. To obtain effective braking with a weak shunt field, excessive armature current is required to develop the desired torque. It should be noted that, with any type of motor, as the motor slows down the countervoltage and current fall off so that the braking effect reduces to a low value at low speed. Where it is desired to maintain the braking torque, the braking resistance may be diminished in steps as the motor slows down.



RUNNING - CLOSE #1 #3 OR #2 #4 ALSO #5-#6-#7-#8 IN SEQUENCE

BRAKING - CLOSE #9

Fig. 3—Principle connections for reversing dynamic braking control for D.C. compound wound motor.

Dynamic braking cannot be obtained on a series motor in the same way as with a shunt or compound wound motor. Dynamic braking to stop a series motor can be obtained, however, by disconnecting the motor from the line and reconnecting armature and field in series with resistance. The result is a severe cumulative braking action and the armature current tends to reach a high value if not properly restricted by resistance. The braking current, flowing through the series winding, serves to supply the field flux. The braking voltage builds up from residual and is thus cumulative, as already mentioned. It should be noted that if the armature and series field were disconnected from the line intact and shorted through resistance, the direction of flow of braking current through the series field would be opposite to its normal flow. The series field would immediately kill the residual magnetism and no braking would result. It is necessary to reverse the series field (or armature) so that the braking current will flow through the series winding in the same direction as the motor current, thus building upon the residual. Fig. 4 shows one scheme of connections used for this purpose.

SEQUENCE OF CONTACTORS

Switch	Forward							Off	Reverse						
	Power			Brake					Brake				Power		
	3	2	1	1	2	3	4		4	3	2	1	1	2	3
1	o	o	o						o	o	o	o			
2				o	o	o	o						o	o	o
3				o	o	o	o						o	o	o
4	o	o	o						o	o	o	o			
5	o	o	o										o	o	o
6				o	o	o	o		o	o	o	o			
7	Closes for slow down on overtravel												Closes for slow down on overtravel		
8	o	o			o	o	o		o	o	o			o	o
9	o					o	o		o	o					o
10	o						o		o						o

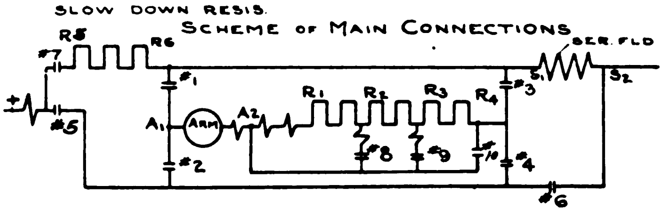


Fig. 4—Connections of series motor with dynamic braking control.

Dynamic braking is more simply accomplished with shunt or compound wound motors. Dynamic braking with the series motor has one distinct advantage, however, in that the braking effect is obtained independent of any outside source of power necessary to excite the fields. Series braking is therefore best suited to such applications as the man trolley drive of a coal or ore bridge. In case power fails as the man trolley approaches its limit of travel, the braking is nevertheless effective, provided the control is such that the braking circuits remain closed.

(To be continued)

NEW METHOD FOR MEASURING PRESSURES IN EVACUATED INCANDESCENT LAMPS.

In one of the papers to be presented at the Meeting of the American Electrochemical Society, April 27, 28 and 29, Dr. Duncan MacRae of the Westinghouse Research Laboratory describes a new method for determining the pressure in a tungsten vacuum lamp. The principle is extremely simple and more accurate than the approximation that has heretofore been made by the well-known use of the induction coil. Dr. MacRae measures the pressures by a McLeod gauge.

Air Required For Combustion of Gases in Steel Plants

A Simple Means of Determining the Amount of Air Required for the Combustion of Various Gases from the Btu. Content of the Gas. Especially Adapted to Steel Mill Furnaces.

By R. T. HASLAM and A. F. SPIEHLER

IN furnace design, especially in furnaces using gaseous fuel, the estimation of the air requirements to obtain the desired results has been a tedious, if not difficult, calculation. It is not usually recognized that there is a direct relation between the Btu per cu. ft. of gas and the air required to burn one cu. ft. By use of this relationship, the determination of air quantities required becomes a rapid and simple calculation.

Table I shows the Btu per cu. ft. and the air required to burn one cu. ft., for several pure gases, combinations of which form almost entirely the combustible components of commercial gases, both natural and artificial. Fig. I shows these points (delta) plotted, Btu vs. cu. ft. air. It will be noted that these points lie along a straight line.

Since this relationship holds for pure gases it should also hold for commercial gases which are nothing but mixtures of these pure gases in different proportions plus various amounts of inert gases such as CO_2 and N_2, which neither require nor furnish air for combustion. Table II gives representative data for the most important types of natural and artificial gases, and by plotting these points, shown as (theta), on Fig. I, they too lie along the same straight line.

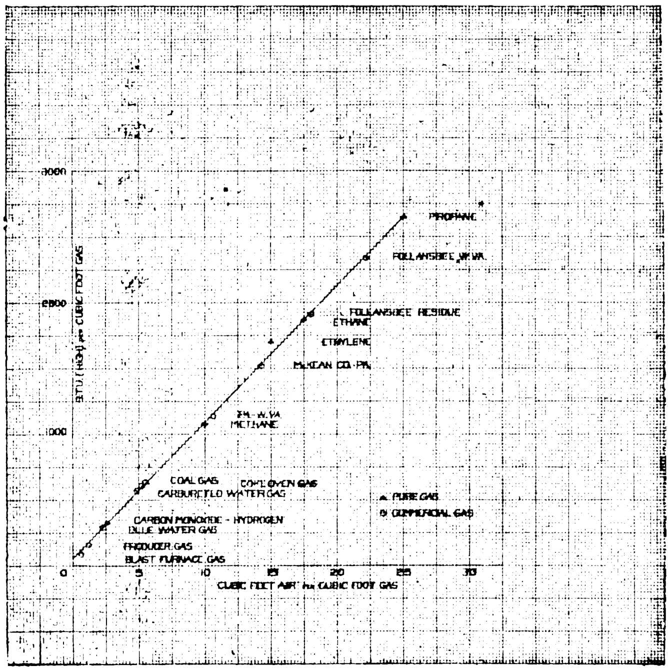


Fig. 1.

It is a well known fact that when the correct amount of any saturated hydro-carbon is burned completely with one cu. ft. of air, a constant amount of heat is evolved.* Thus, if methane is burnt with one cu. ft. of air, the heat evolved will be the same as when propane or any other saturated hydro-carbon is similarly burned with one cu. ft. of air. Ethylene, an unsaturated hydro-carbon, does not fall exactly on the line in Fig. I, but the deviation is not excessive, and as the percentage of ethylene in gases is usually low, the effect of its deviation on commercial gases is negligible. The other unsaturated hydro-carbons, propylene, etc., also deviate, but not as much as ethylene, so in this case the result is again negligible. The only other constituents of any importance in commercial gases, which are not saturated or unsaturated hydrocarbons are hydrogen (H_2) and carbon monoxide (CO). Fortunately, the points for these two important constituents fall along the line, making the relationship complete. Acetylene deviates so widely from the line, that it must be called an exception. Consequently the relation holds for all commercial gases except acetylene.

Fig. I shows that when Btu per cu. ft. of gases are plotted against the cu. ft. of air required, a straight line results, thus allowing a simple formula to connect one with the other. The general equation for this type of line is of the form $y = a + b X$, and for this line in particular the equation becomes

$$\text{cu. ft. of air theoretically needed to burn 1 cu. ft. of gas} = 9.67 \frac{\text{Btu}}{1{,}000} - .53$$

where, Btu equals higher heating value in British Thermal Units per cu. ft. of combustible gas.

A rough approximation of this formula for quick estimates is—cu. ft. of air theoretically needed to burn

$$1 \text{ cu .ft. gas} = \frac{\text{Btu}}{100} - .5$$

This formula gives the cu. ft. of air **theoretically** required to burn one cu. ft. of any gas, but as some excess air is always used, the true amount of air required can be obtained by merely adding to the value found, the percentage excess air considered necessary for any particular operation.

This formula also shows that for a given heat effect, the amount of air required is constant, irrespective of the gaseous fuel used. That is, if a million Btus are desired per hour in a furnace, the amount of air required for this effect is the same whether producer gas or natural gas is used, thus no change of air supplying equipment is needed for a change from one type of gas to another. This assumes the efficiency in the use of each gas is the same.

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*Thornton Rule.

This formula is particularly useful because Btu data on gaseous fuels is always either available or easily determined and from this the air required per cu. ft. of gas may be calculated easily. As the total heat required is also usually known the total cu. ft. of air and cu. ft. of gas required are readily determined.

TABLE I.

Pure Gases.

Gas.	Btu/cu. ft. (high)	Cu. ft. air required (theoretical)	Source of data.
Propane C_3H_8	2650	25.0	Landolt-Bornstein
Methane CH_4	1070	10.0	"
Ethane C_2H_6	1870	17.5	"
Ethylene C_2H_4	1710	15.0	"
Carbon Monoxide CO	322	2.5	"
Hydrogen H_2	324	2.5	"

TABLE II.

Commercial Gases.

Follansbee, W. Va. (Nat.)	2351	22.17	B. of M.	T.P.	10
Residual Follansbee (Nat.)	1913	18.03	"	"	
McKean Co. Pa. (Nat.)	1519	14.28	"	"	158
Pa. W. Va. (Nat.)	1132	10.64	"	"	10
Coal Gas	632	5.52	"	"	
Carbureted Water Gas	572	4.89	"	"	
Blue Water Gas	299	2.32	Actual Analysis		
Producer Gas	154	1.21	"	"	
Blast Furnace Gas	86	0.68	"	"	
Coke Oven Gas	607	5.24	"	"	

The Possibility of Improved Methods of Rolling Sheet Steel

Author Does Not Think That a Continuous Sheet Mill Is Impossible—However, He Believes Extensive Scientific Experiments on the Problem Should Be Conducted.

By SUMMER B. ELY, Professor of Commercial Engineering,
Carnegie Institute of Technology, Pittsburgh, Pa.

PROBABLY the first iron plates were made by hammering and must indeed have been a crude production. About the year 1725 or 1730, however, rolls seem to have come into use, although it was a number of years later before anything resembling a thin sheet was made; yet from that day to the present time the same general type of machinery has been used for rolling sheet steel. To be sure, our sheet mills of to-day compared with the early ones would appear giants in size and strength; yet, after all, what real difference is there except this increase of size and strength? Why have we no automatic mills to turn out sheet steel, or at least automatic devices to reduce labor? This is the question asked by everyone who is familiar with the machinery and methods used in the manufacture of heavier steel products, such as billets, bars, rods, plates, etc. We have no continuous sheet mills, we do not even use roller-driven tables, automatic guides, etc. Practically everything is done by hand.

This statement may need a little qualification. Occasionally we do come across some small devices in use; such, for instance, as a hinged or pivoted table to assist the catcher in returning the pack over the top of the rolls to the roller. This particular device does not save any labor in the sense of fewer men being employed; it is merely a help to the catcher. Some devices, such as shifting tables and auxiliary attachments to cold rolls, may have a tendency to cut down the labor force; but, after all, such small helps as these are not real changes in the machinery of sheet rolling, and, furthermore, are far from being universally used. Many plants, probably most plants, do not use such devices; or, if they do, only an occasional mill in the plant is thus equipped.

It would seem, however, as if some device might be gotten up to cut down the number of men needed about a sheet mill. A mechanical catcher, for example, which would automatically catch the pack of sheets as it came through the rolls, lift it up, and return it to the roller. Such a device would seem to be a mechanical possibility and probably could be made to work successfully. Why has not some such device been worked out, perfected, and sold with each sheet mill as part of its regular equipment?

There are probably a good many answers to this question, but it must ultimately come down to a matter of dollars and cents. What will the device cost and how much will it save? If the saving is enough, it does not make any difference what the attitude of the labor union is, sooner or later the manufacturer will introduce it, as has been demonstrated again and again in other industries. But the fact remains that such devices are not in universal use and it would seem as if the amount of saving was not sufficient to act as a real incentive. However, if the question of saving is in doubt in the case of improvements such as I have mentioned, there can be no doubt of a tremendous labor saving, if a successful continuous sheet mill could be devised. Somebody has made the statement, that any steel product, if enough of it is to be rolled and its size is uniform enough, must ultimately be made on a continuous mill. No other form of mill can compete; and this statement perhaps will come true of sheet steel some day. In the past, many attempts have been made and some very expensive continuous sheet mills have been built; and so, while there have been improvements in methods and practice, yet as I have said, the machinery is much the same as it was 200 years ago.

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*Abstract of paper read before the Engineers' Society of Western Pennsylvania.

There is no doubt that to roll thin sheets of steel or iron is a most delicate operation and its success depends on many things. You occasionally hear a sheet mill roller say that the weather is not right to-day and he cannot turn out a satisfactory product; which simply means that some detail is wrong and he is unable to find what it is. One also hears stories from sheet mill superintendents to the effect that after having the windows of the mill cleaned, the rollers have trouble until they accustom themselves to judge the heat of the steel in the brighter light; and one can readily believe this.

In the manufacture of heavier steel products the temperature to which they are heated are high, comparatively, and there is some latitude, but with sheet steel the heat must be just right. Even starting with the bar, say, as it comes from the furnace for the first pass in the mill, if it is too cold the scale will not be lifted and this scale rolls into the sheets, making a rough surface and causing the sheets to stick together later when they are rolled in packs. If the sheet mill could receive only bars that were perfectly clean, perhaps if the material were a little too cold no harm might be done, but all commercial bars carry scale and this must be taken into account.

However, if instead of the bar coming too cold from the pair furnace, it is a little too hot, there is still worse trouble. The large sheet rolls will get hotter than the roller anticipated, will expand, and the line of contact between them will not be correct; and, in addition, as the bar is too hot it will be softer than it should be, and will not spring the rolls the desired amount. The consequence of this is that the bar when worked down on the chill rolls will produce a sheet round on the back end—that is, thinner in the center than at the sides—whereas, probably the bar rolled before this had the proper temperature and produced a sheet that was not long in the center, but long on each side, having what the roller calls "horns." A round-end sheet indicates that the rolls are "full" in the middle and horns show that the rolls are "hollow." Now when a circular-end sheet is placed on the top of a horned sheet, reheated and put into the rolls together, the pack will either pinch or run off at the back end—that is, the sheets will spread one from another on the back end of the pack, due to the uneven drawing. And even if the roller, by great care and judgment in adjusting the draft screw, is able to prevent a pinch, the scale which is produced from being too hot will lift only in spots, sinking into the sheets and causing the pack to stick together in patches, so that the sheets cannot be pried apart without tearing.

Everyone familiar with sheet rolling realizes that the rolls must be kept at the proper heat so that they will be kept the proper shape to roll such a thin product successfully. A roller may (probably unconsciously) count on a certain spring to the stand of rolls, and by trial find the proper heat to go with it, so as to keep the shape of his rolls right; and he will watch carefully the size of the horns on each sheet as this is an indication of the shape of the mill. He knows that if he rolls too fast, and does not allow time enough between passes, his rolls will lose their shape. Neither must he roll too slow. Again, sheets always entered at the same place on the roll may cause trouble. He must constantly watch and guard against such things as cold drafts of air blowing on the rolls, and anything that will affect the temperature of the roll. Of late years some of these difficulties have been remedied by burning gas against the rolls to expand them when not in operation, or by blowing steam on working rolls to keep down the expansion.

Another most important factor is the roll-neck friction, and the extent of this is not always realized. For example, when finishing a pack, if one neck of a roll be greased (with hot neck grease) without greasing the other, the pack will always draw a long horn next to the neck that is dry. The reason is that the friction on the ungreased neck is greater and consequently heats and expands the roll on that side. Undoubtedly a large percentage of power is used in overcoming roll-neck friction. I have reason to think it is anywhere from 60 to 90 per cent although there are no definite figures to go on. This is one of the most important things in roll design and yet we have no scientific information on the subject. If we had, it might lead to some radical changes.

On hot-roll sheet mills at work, a blue or indigo color is often observable and this will correspond to a temperature of about 550 degrees F. This temperature will often run higher, although when reaching 750 degrees, showing a gray, the roll is liable to break shortly afterwards. In a perfectly dark room probably 900 degrees F. would give the roll a perceptible red color. Naturally, the roll is hotter in the center than at the ends and the necks are cooler for, although grease is often seen burning on the neck, the temperature at which the grease burns is generally lower than the temperature of the roll as indicated by its color.

In the history of sheet rolling there has been a tendency to increase the diameter of the rolls continually, until today sheet rolls of 30 inches are seen and I understand rolls as large at 32 inches have been used. The larger the roll, the more tonnage can be turned out, as a large roll does not change its temperature as readily as a small one. There is evidently a limit to the size however (aside from practical considerations of handling such heavy rolls), for the larger the roll the more the radiating surface to cause cooling (The fact that the volume varies as the cube and the surface only as the square of the diameter, has only an indirect relation to this problem of cooling). Also, the larger curvature will not draw the steel as much for the same total pressure.

As far as the breakage of rolls is concerned this is apparently due to unequal expansion, and not to the stress of rolling; as evidenced by the fact that rolls sometimes break when the roll is standing still, the roll train perhaps having been stopped for a few moments during the working period.

Considering now the possibility of a continuous sheet mill, it will be remembered that the United States Steel Corporation spent a very large sum of money at Farrell, Pa. A complete plant was built and in it was installed a continuous sheet mill which consisted of a series of stands of ordinary two-high sheet mills in tandem—the sheet passing through one stand after another, never being in two stands at the same time; and the sheets were automatically doubled and matched together in special devices at certain points in the train. This was about 1906 or 1907. It was thought, even if it were impossible to roll the lighter gages such as 26 and 28, that 18 or 20 gage could be successfully rolled. After this mill had been given a most thorough trial it was given up, the mill was dismantled, and the ordinary method of sheet rolling installed.

This is a convincing and definite proof of the great difficulties of sheet manufacture by using our present roll stands in a continuous train. Aside from any other question the difficulty of keeping so many different rolls in a like expanded condition and shape seems insurmountable. The present method of using gas and steam on the rolls which was not known at that time, might have aided a little; but something a good deal more certain than this must be devised if light gages are to be rolled in this manner. Possibly the heavier gages, say, 10 and 12, could be made in this way, but we already have satisfactory mills of a different type for this purpose and we would be no further along towards automatically rolling light-gage sheet steel.

Some method of absolutely heating the steel to a definite temperature—possibly some form of electric furnace—and some way of keeping the shape of the roll must be devised. Rolls have been cast with holes through the center and steam introduced or gas burned inside them; but they have been found inadequate to hold their shape and stand up to the service. The practice already mentioned of using gas and steam on the surface of the rolls is more satisfactory. Perhaps some day rolls will be placed inside a constant temperature furnace, but what would be done about the bearings and other details is a question.

Some twelve or more years ago I visited a continuous sheet mill in the town of Teplitz in Northern Austria. This is an extremely interesting mill and the only one of its kind I ever heard of. There are five stands of two-high continuous rolls, all being alike, having a diameter of 23⅝ inches and a length of 59 inches. In front of this is a small set of three-high rolls, and to the right a larger set of three-high rolls. An eight-inch slab is delivered to the large three-high mill and broken down to three or four inches in thickness. This slab is then cut in half and put into a reheating furnace, the furnace not being shown on the drawing. One of these halves then goes to the small three-high mill and is reduced to 9/32 of an inch (7 mm.) in thickness and then without reheating is put into the continuous stands. This thickness (9/32 inch) is always the same, and the reduction is varied on the continuous mill to give the required final thickness.

The sheet is finished about 60 feet long and is, of course, in all the stands at the same time. Sheets are always rolled singly and never in packs or doubled. They are from 40 to 50 inches wide. The stands are about nine feet from center to center and no idle rolls or automatic tables of any kind are used—simply stationary guides six or eight inches high and a cast-iron plate between the stands on which the sheet slides. The gear train gives the first stand rolls 30 rpm, the next 37.5, then 45, 52.5, and 60 for the last stand. When I saw the mill it was rolling a final product of 12 gage, making a total reduction in the five stands of some 58 per cent (from 7 mm. to 3 mm.).

Several points of great interest present themselves in connection with this mill. The first is the fact that such a thin piece of steel could be in all the five stands of rolls at the same time and not either tear or be crumpled between them. Right here there is a great deal of confusion as to the pull exerted by rolls generally on steel and for this reason I want to digress for a moment. You will remember that a paper on the theory of the rolling-mill was read by Professor W. Trinks,* before this Society. In this he says: "Most people think that the steel is pulled through the rolls with great force. As a matter of fact there is little if any pulling action." This of course supposes the steel free and not held by any outside force.

This continuous mill has demonstrated the fact that not only can the shape of the rolls be controlled but the speeds and drafts among the various stands can be properly adjusted, at least for single sheets as thin as 14 gage.

Another point of great interest is the fact that the back end of the sheet comes out thicker than the front end, due to the rapid loss of heat while in the continuous rolls. To work this mill economically it must work these long lengths and it is their practice to cut the 60-foot sheets into short pieces, and afterwards sort the corresponding thicknesses from the different long lengths together; so that the variation of thickness would not be noticeable to customers.

I was told that the mill was not a great financial success as there was not demand enough to keep running steadily on these particular gages. Furthermore, the engine running the continuous mill was about 1,000 horse-power normal rating and totally inadequate to run the mill satisfactorily. They said they wanted to buy a larger engine but had no money. I never heard whether or not another engine was installed, nor do I know what happened to this plant during the war.

They had experimented very little with trying to roll two sheets in a pack. The furnace lay-out made it almost impossible to do so. However, the little that had been done seemed to show, as one would expect, that the thinner the sheet the greater the non-uniformity of thickness. It would seem that a reversing two-high mill, receiving alternately the hot and cold end of the steel might equalize this thickness and possibly be more satisfactory than the five continuous stands. So the question would naturally arise, what is the best way of rolling 12 and 14 gage. Then too, it would be impossible to take this 12 or 14 gage rolled on a special mill and finish it on the ordinary two-high sheet mill. Shapes of sheets and rolls will not fit and while one or two packs might be rolled with care, the scrap loss would be enormous and this has been tried commercially and failed. It has also been suggested and thought possible to reduce the cost of sheet rolling by starting with the product from a universal plate mill instead of a sheet bar mill. If a universal plate of seven or eight gage and of accurate width were cut to proper size it would be equivalent to doing away with some of the present roughing down process. However, when the price of the universal plate is taken into account there is little or no gain, and, in addition, the difficulty of doing good work has been very greatly increased.

Speaking of a reversing mill, at first thought it would appear that sheets might be successfully rolled in packs on a two-high reversing mill. The condition of the same two rolls in the same relation to each other and the same pack of steel is what we have in the commercial mill now; and certainly, with reversing roller tables, etc., a large saving in labor would result even if the tonnage per set of rolls were not increased. However, it must be remembered that in a reversing mill, first one end of the pack and then the other would be entered, and this thin pack of sheets would have to be first drawn in one direction and then in the opposite direction; and that the two ends of a pack are not alike. So that we really have a very different condition from the ordinary two-high stand.

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*June 1920, v. 36, p. 275.

This sheet machinery problem is a real problem, but to say or predict that a continuous sheet mill, for instance, is an impossibility, reminds me of my friend the physician who said: "A doctor should never tell a patient he is going to die, because, you know, he might get well." And, while the outlook at the present moment is not encouraging, I am one of those who believe the solution will one day be found.

To my mind, the only logical way to approach this problem is from the scientific experimental side. It has been pretty well demonstrated that practice cannot furnish enough information. We need more knowledge of what actually occurs in rolling—what are the pressures, heat distribution, radiation, friction, etc. Who knows what per cent. of mechanical energy is turned into heat during a pass?

When enough data and information are at hand, new ways and means, as always happens, will be indicated. Our way of looking at the old facts will be different and from another point of view. Find out the underlying principles and causes first, and build elaborate experimental plants afterwards—not before, as has been the case in the past.

Heat Treating Steel For Structural Parts

Illustrating Means of Estimating Carbon Content from Microstructure After Annealing—The Comparison of the Effects of Heat Treatment on Various Steels from Mild to Tool Steel.

By HORACE C. KNERR,
Metallurgist-Naval Aircraft Factory.

EXECUTIVES, engineers, designers and mechanics, engaged in the production of such specialties as high grade machinery, engines, automobiles and airplanes, seldom have the time to study deeply into the characteristics of their most indispensable material, steel. To many of them it is simply a strong, hard and tough metal of moderate cost, which can be depended upon to meet certain exacting requirements if properly handled. Its strength in tension, compression and shear can be obtained from reference books, and if it is "good steel" it will not be too difficult to work, and the finished parts will stand a lot of wear and abuse without going to pieces. "Heat treatment" is sometimes looked upon by the layman as a sort of mystic ritual whose proper place was once the forge and tool shop, but which has, through bad luck, recently horned its way into the factory proper, and onto the blue print and specification; and long-winded discussions of which have been taking up an inordinate amount of space in hitherto sensible trade journals, along with a lot of weird terms, and photographs resembling a Cubist's idea of a violent earthquake on lower Broadway.

Few who are not actually engaged in metallurgical work have either the leisure or the inclination to undertake a detailed study of the principles and terms used in connection with heat treatment and the microscopic study of the principles and terms used in connection with heat treatment and the microscopic study of the structure of steel. But many who work with steel would be glad to have more light on the fundamentals of this subject, which is now taking so important a place in the manufacture of high grade parts. An intelligent grasp of the principles of heat treatment as a process and of the use of the microscope in judging the merits, quality and condition of a piece of steel is well worth the while of many who do not care to qualify as metallurgists.

Such terms as "critical range, pearlite, ferrite, sorbite, martensite, eutectoid, normalize," etc., frequently appear in papers and discussions on steel, and the man whose training has been along other lines than metallurgy quite naturally finds much to be desired in respect to clearness.

The purpose of the present paper is to attempt a brief and non-technical review of some of the essential points in the metallurgy of steel such as is used in the fabrication of mechanical parts. Tool steels and special alloys will not be discussed, as their field is more complex. The significance of critical points, the nature of various constituents in the microstructure of steel, the influence of carbon content on the microstructure and physical properties, and the effect of common alloys, will be touched upon. Illustrations will be given showing the relation between heat treatment, microstructure and physical properties in some steels of varying carbon content.

STRUCTURAL COMPOSITION OF STEEL

Crystalline Structure.

Steel is essentially an alloy of the elements iron and carbon. Minute quantities of other elements, such as manganese and silicon, are nearly always present, as are also the impurities, sulphur and phosphorus. Manganese is introduced purposely, as it acts as a scavenger for sulphur. The others exist in the raw materials and it is almost impossible to entirely remove them.

The metal, iron, is crystalline in structure. The crystals are generally microscopic in size. Steel partakes of the crystalline nature of iron. When a properly prepared specimen of iron or steel is viewed under a microscope at a magnification of about 100 diameters or over, the crystals can be clearly seen in section. See Fig. 1, practically carbonless iron. The crystals are usually called grains. The term grains as here used should be distinguished from grain as applied to wood. Correctly speaking, steel has not the latter type of grain, although its behavior and the appearance of its fracture may often suggest such a fibrous condition. Hammering, rolling or drawing may distort the crystalline grains, and some-

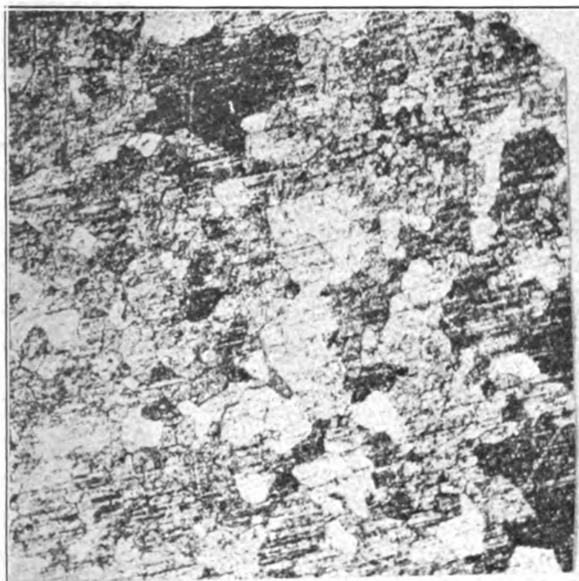

Fig. 1—Practically carbonless iron. Showing grain structure.

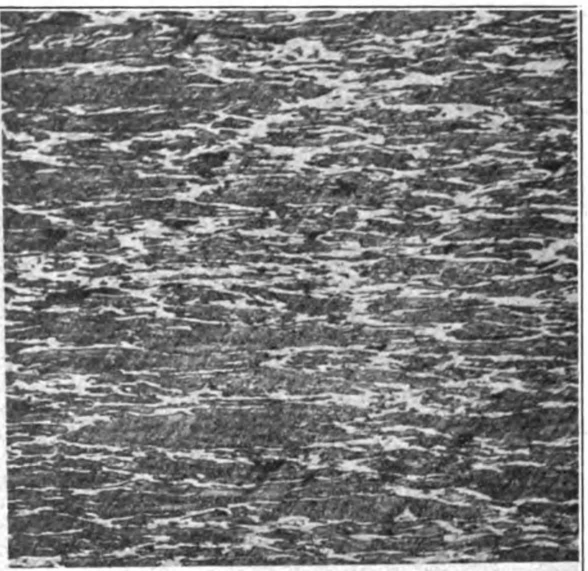

Fig. 2—Longitudinal section of steel bar, as rolled. Grains elongated in direction of rolling.

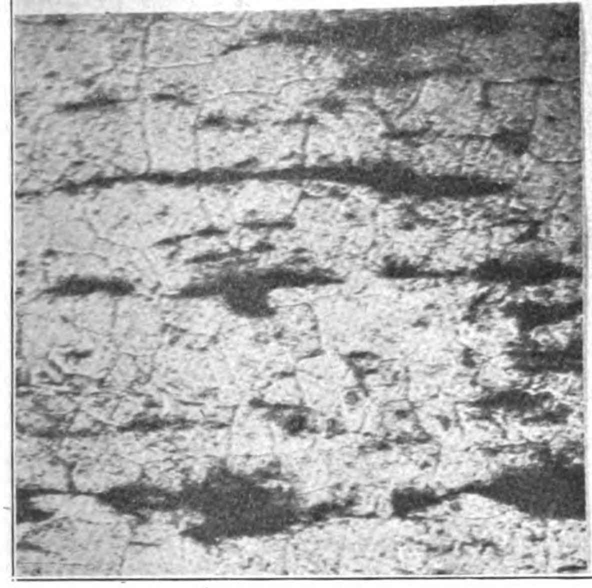

Fig. 3—Longitudinal section wrought iron, annealed. Streaks of slag, which give fibrous appearance. True grains may be seen, and are not elongated.

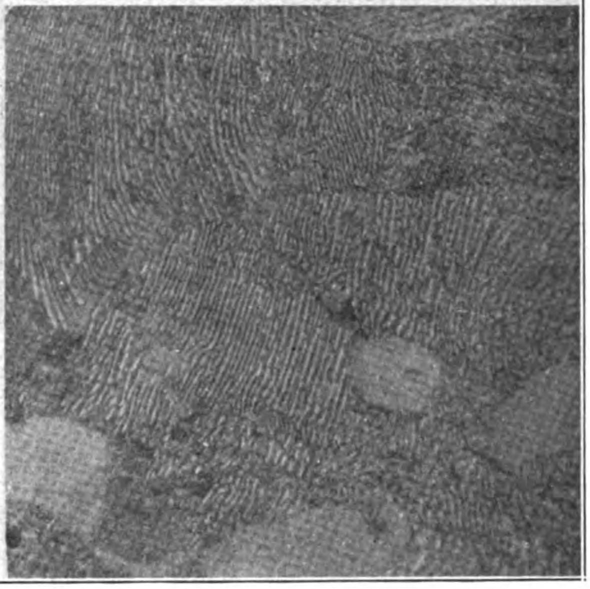

Fig. 4—Pearlite (lamellar) and Ferrite (smooth). Exceptionally large formation.

All specimens etched with 2% Nitric Acid.

All photomicrographs magnified 500 diameters, except where noted.

times greatly elongate them, giving somewhat the effect of grain in wood. This is illustrated in Fig. 2, a longitudinal section through a drawn bar of steel. Wrought iron, due to the presence of streaks of included slag, drawn out in rolling, may also have the fibrous appearance characteristic of the grain in wood. This is shown in Fig. 3, a longitudinal secton of annealed wrought iron. The black streaks are slag, but the crystalline grains can be clearly distinguished, and are not elongated.

Carbon Content.

The hardening properties of steel depend fundamentally upon the amount of carbon it contains. The quantity required is very small, seldom exceeding 1½ per cent in the hardest steels. Steels for structural parts range in carbon content from practically carbonless iron having slow strength but great softness and ductility, up to spring steel containing as much as 0.90 per cent carbon, and certain parts requiring great hardness and resistance to wear, such as bearing surfaces, which may have about 1.0 per cent carbon. The tensile strength of steel increases with carbon content up to about 0.90 per cent, but the ductility or ability to withstand bending or drawing decreases. Both tensile strength and ductility decrease rapidly above 0.90 per cent carbon and such steel is therefore brittle and not suitable for structural parts.

Only steels having a carbon content of not over 0.90 per cent will be discussed here.

Cementite and Ferrite.

The carbon in steel unites with a definite amount of the iron as a chemical compound, the carbide of iron,

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whose chemical symbol is Fe_3C. This carbide, known to metallurgists as "cementite," is the real hardening constituent of steel. It is an extremely hard substance, being practically as hard as glass, and is also very brittle. There is no free carbon in steel, it all goes into combination with iron as cementite. The remaining iron is free from carbon and is called ferrite. It is very soft and ductile.

Pearlite.

In steel which has been slowly cooled from a high temperature, or "annealed," all the cementite forms a mechanical mixture with a certain definite proportion of ferrite (carbonless iron), in the form of alternate thin layers or laminations of cementite and ferrite, and which, owing to its appearance under the microscope, is known as "pearlite." This is clearly illustrated in Fig. 4.

Annealed steel whose carbon content is approximately 0.90 per cent consists entirely of pearlite and this is called "eutectoid steel." If the carbon content is less than this the steel will consist of a mixture of pearlite and free ferrite. This is called hypo-eutectoid steel. If more than 0.90 per cent carbon is present there will be an excess of free cementite surrounding the grains of pearlite. This is called hyper-eutectoid of steel. The latter condition tends to cause extreme hardness and brittleness.

Metallographic Analysis for Carbon.

The pearlite itself is always of eutectoid composition; that is, it always contains about 0.90 per cent carbon. (The exact amount varies slightly with the composition of the steel and the treatment it has received, perhaps from 0.85 per cent to 0.95 per cent.) This fact affords a convenient and reliable way of estimating the carbon content of a specimen of steel, without the need of chemical analysis. The specimen is fully annealed, a section cut through it, polished by means of successively finer grades of emery and polishing powder, to a mirror-like finish, etched with dilute nitric acid (2 per cent) and examined under the microscope.

If the carbon content is approximately .90 per cent, the structure will be entirely pearlitic.

If the carbon content is less than about .05 per cent, as in soft iron, no pearlite will appear.

If the carbon content is 0.45 per cent a structure consisting half of pearlite and half of ferrite will appear, the pearlite being dark and the ferrite bright. If the carbon content is 0.30 per cent the structure will consist of one-third pearlite and two-thirds ferrite, and so on, the proportion of pearlite to the entire mass always being the proportion the carbon content bears to 0.90 per cent. This can be expressed by the formula

$$\text{Per cent carbon} = \frac{\text{Pearlite area}}{\text{Total area}} \times 0.90$$

With practice, the carbon content can be estimated by this method with plus or minus 5 points (.05 per cent).

In specimens whose carbon content is greater than about 0.90 per cent the carbon content can be approximated by estimating the amount of excess cementite which appears as a network about grains of pearlite. This is not, however, of interest here, as such steels are not used in construction on account of their brittleness.

Annealing.

In the foregoing paragraphs steel has been considered in its annealed condition.

Annealing consists in heating the metal above a certain high temperature ("critical range" described below), generally a bright red heat, and causing it to cool slowly, as in the furnace. This leaves the steel with a structure consisting of grains of pearlite, surrounded either by free ferrite or cementite, according to whether the carbon content is below or above .90 per cent, as previously explained.

Heating much above the critical range or holding for too long a time above the critical range causes the grains to enlarge. Coarse grain structure is very objectionable as it tends to weaken the steel and make it brittle.

Normalizing may be considered as a form of annealing. It has been defined as heating the steel slightly above the critical range, and cooling in air. This serves to remove internal stresses in the metal that may have been set up in cold working, and to produce a fine and uniform grain structure.

Fig. 5—Annealed—Heated to 1650 deg. F. and cooled in air. Pearlite—Ferrite.

Yield stress	30,000
Ultimate stress	40,000
Elongation 2-in.	45%
Brinell hardness	100

Fig. 6—Hardened—Heated to 1625 deg. F. and quenched in oil. Sorbite and Ferrite (carbon too low for complete hardening.)

Yield stress	50,000
Ultimate stress	65,000
Elongation 2-in.	25%
Brinell hardness	135

Fig. 7—Tempered—at 850 deg. for 30 minutes. Sorbite passing into pearlite and ferrite.

Yield stress	45,000
Ultimate stress	60,000
Elongation 2-in.	30%
Brinell hardness	125

Fig. 8—Annealed—Heated to 1600 deg. F. and cooled in still air. Pearlite—Ferrite.

Medium (low) Carbon steel. Carbon 0.30%.

Yield stress	40,000
Ultimate stress	60,000
Elongation 2-in.	27%
Reduction of area	55%
Brinell hardness	150

Fig. 9—Hardened—Heated to 1575 deg. F. and quenched in oil. Sorbite with some ferrite. (Hardening not entirely complete due to comparatively low carbon.).

Yield stress	80,000
Ultimate stress	90,000
Elongation 2-in.	15%
Reduction of area	40%
Brinell hardness	200

Fig. 10—Tempered—at 900 deg. F. for 30 minutes. Sorbite, passing into Pearlite and Ferrite.

Yield stress	60,000
Ultimate stress	80,000
Elongation 2-in.	22%
Reduction of area	50%
Brinell hardness	170

Critical Points.

The heating of steel to high temperatures, although considerably below the melting point, causes very important changes to take place in its condition. These internal changes are accompanied by certain phenomena, such as the release or absorption of heat, abrupt expansion or contraction, changes in magnetic qualities, etc.

The transformations for a given steel take place at certain definite temperatures, called transformation points, or more commonly "critical points." Broadly

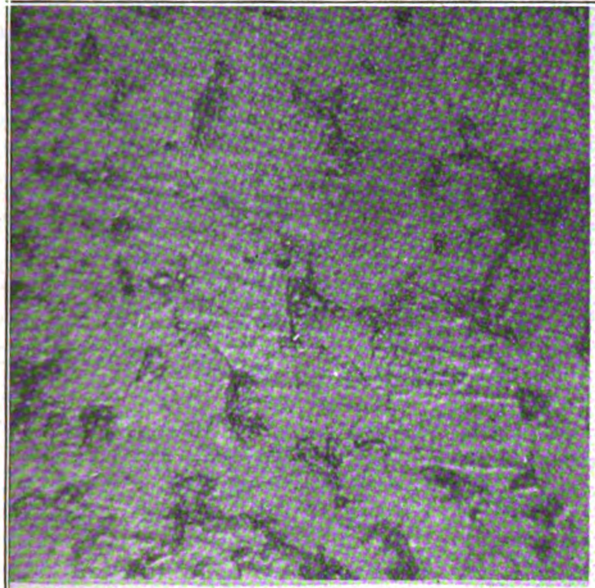
Fig. 5.

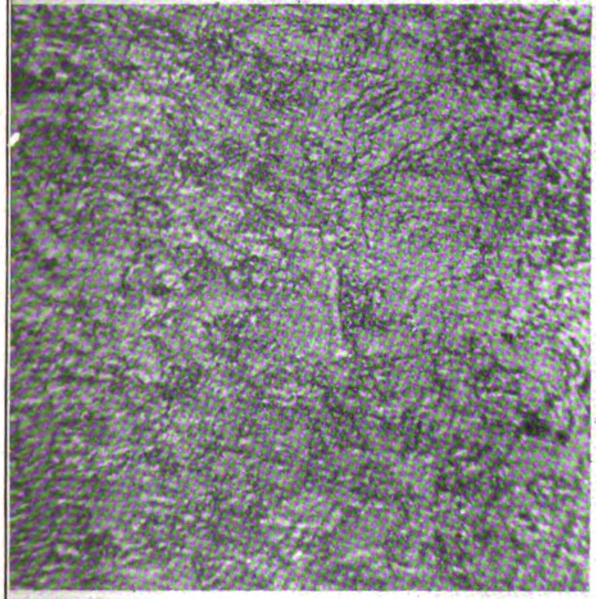
Fig. 6.

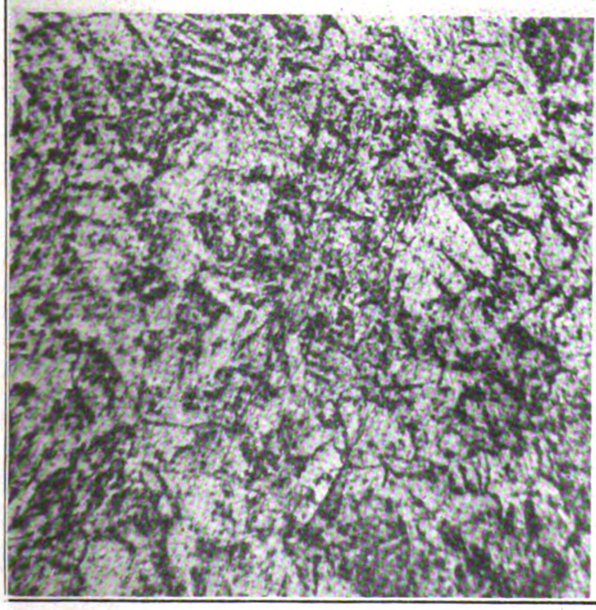
Fig. 7.

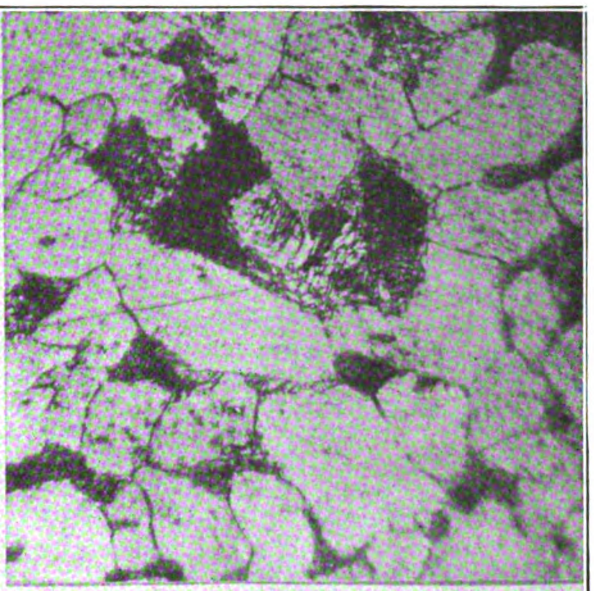
Fig. 8.

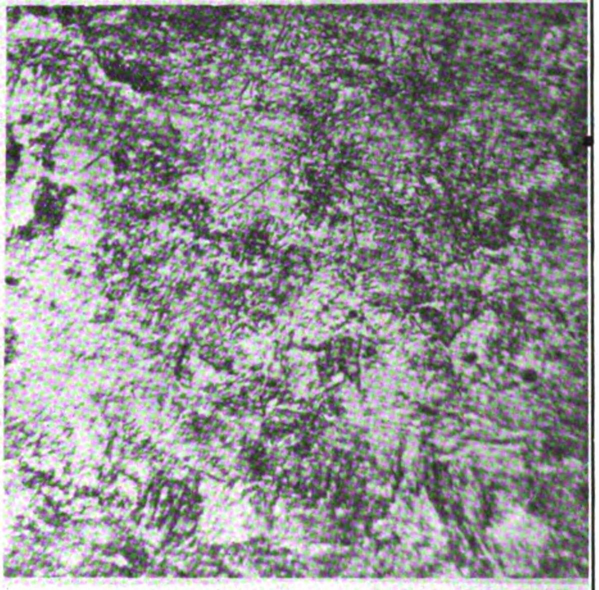
Fig. 9.

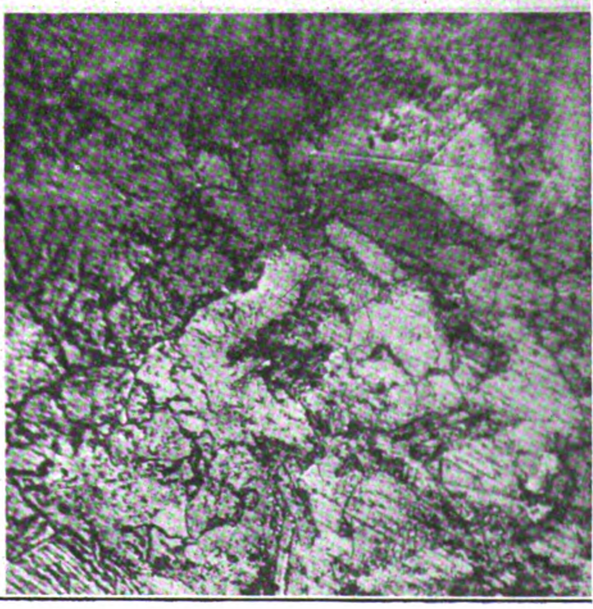
Fig. 10.

speaking, low carbon steel has three critical points, medeium carbon two, and high carbon one. The limits of temperature between which the critical points occur are called the "critical range" of the steel. The position of the points is affected by the chemical composition of the steel and also upon the rate of heating or cooling.

The critical range is lowered with an increase in carbon up to the eutectoid composition, 0.90 per cent carbon. Other elements, such as nickel, chromium, manganese, tungsten, etc., have a strong effect on the critical range, some tending to raise and others to lower it. This will be more fully discussed under alloy steels.

The critical points are reversible on heating and cooling. That is, if certain changes take place in a piece of steel when it is slowly heated to above the critical range, equal and opposite changes will take place on slowly cooling it to below the critical range. For example, on a rising temperature, there will be a sudden absorption of heat, a loss of magnetic properties, and a halt in the expansion of the metal, while on a falling temperature heat will, at a certain point, suddenly be given off, magnetic properties regained, and contraction momentarily cease. The changes on cooling will take place at somewhat lower temperatures than they did on heating, that is, there is a lag in the cycle. The position of the transformation points is affected by the rate of heating or cooling. They will be higher if the piece is rapidly heated, and will be lower if it is rapidly cooled.

Hardening or Quenching.

The hardening power of steel depends upon changes which take place in its condition on heating it above the critical range. Sudden cooling prevents the steel from returning to the pearlitic condition which it has after slow cooling.

When steel which has been heated above its critical range is suddenly cooled to normal temperature, as by quenching in oil or water, a homogeneous mass of fine structure and maximum hardness results. This is very different both in appearance and properties from the pearlite and ferrite obtained by slow cooling. With high carbon steel and certain medium carbon alloy steels this mass will consist of "martensite." Next to cementite, martensite is the hardest and most brittle constituent of steel. It has a structure suggesting a triangular network of needles. Individual grains cannot ordinarly be distinguished. Lower carbon steels when quenched will yield "sorbite," a softer and more ductile substance than martensite, but harder and tougher than pearlite.

Still lower carbon steels will yield a mixture of sorbite and ferrite when quenched. Illustrations of these structures are given further below. Figs. 5 to 10.

Quenching from temperatures lower than the critical range will result in practically no hardening, and if the quenching temperature lies within the critical range the hardening will be partial.

Heating much above the critical range for quenching will produce a coarse structure and tend to cause brittleness and other ill effects.

Accurate control of quenching temperatures, by means of reliable pyrometers, is therefore essential.

Steel which has been quenched is generally too hard and brittle for structural use, and contains severe internal hardening strains set up by the unequal contraction of the mass in sudden cooling. These strains are likely to cause cracks, and must always be removed by the operation known as tempering.

Tempering or Drawing.

Tempering, sometimes called drawing, consists in reheating hardened steel to certain temperatures below the critical range, generally followed by allowing to cool in air.

In addition to relieving internal strains caused by quenching, tempering reduces the hardness and increases the ductility, at the same time lowering the tensile strength of the steel. By varying the tempering temperature from a few hundred degrees Fahrenheit up to the critical range, various combinations from maximum hardness and tensile strength and minimum ductility, to minimum hardness and tensile strength and maximum ductility are obtained.

This is accompanied by corresponding changes in the microstructure.

With increasing temperature the martensite of hardened steel breaks down into the softer and more ductile sorbite, and the sorbite into a still softer mixture of sorbite and finely divided ferrite, and finally, as the drawing temperature reaches the critical range the sorbite resolves into pearlite with the complete seperation of the excess ferrite, as in annealed steel.

Troostite.

In passing from martensite to sorbite, an intermediate condition occurs, known as troostite, and appearing as dark spots on the background or matrix of martensite. The exact nature of troostite is somewhat in doubt, but it is generally regarded as a transitional stage of martensite breaking down into sorbite, or a conglomerate of the two. It is softer and more ductile than martensite, but harder and less ductile than sorbite.

Alloy Steels.

By adding to steel small quantities of certain metals such as nickel, chromium, vanadium and molybdenum, singly or in various combinations, its physical properties can be very greatly improved. The first three are the most extensively used alloys for steel intended for structural parts, and molybdenum is taking an important place. Larger quantities of manganese and silicon than ordinarily present in steel, and other alloys such as tungsten, zirconium, etc., also have important functions for special purposes.

Each of these alloys has its characteristic effect, and the particular amount of each which is the most desirable has definite limits. All of them depend upon proper heat treatment to produce the desired results. This fact is often overlooked by users of steel, to their considerable disadvantage. The effectiveness of the alloys also varies largely with the amount of carbon in the steel.

Nickel may be added economically, up to about 4 per cent. Above this an increase in nickel is not repaid by a corresponding improvement in properties, and in certain quantities is even harmful. The presence of about 3½ per cent of nickel greatly increases both the tensile strength and ductility of a steel of given carbon content after proper heat treatment. As with carbon, the critical range, and consequently the quenching temperature, is lowered with an increase in nickel. Without heat treatment, nickel has very little effect on the properties of steel.

The presence of nickel cannot be detected by means of the microscope, as it goes into solution much as salt does in water, and does not form any recognizable constituent.

Chromium is generally added up to about 1.75 per cent as a maximum, smaller amounts being more common. Alone, it increases the ability of the steel to harden in quenching, but also tends to cause brittleness. It raises the critical range. Chromium is most profitably used in conjunction with one of the other alloys, nickel, vanadium or molybdenum, as these counteract the brittleness found with chromium alone, and great tensile strength and toughness result.

Vanadium and molybdenum are somewhat similar in their action, being most valuable as enhancing the effect of another alloy, usually chromium. They are used in very small quantities, 0.15 per cent being customary for vanadium and about 0.25 per cent to 0.50 per cent for molybdenum. Both of them toughen the steel, that is, they increase the ductility for a given tensile strength, and they also increase the tensile strength. Vanadium raises the critical range. Molybdenum has the remarkable and very valuable effect of widening the limits within which it is safe to vary the quenching temperature, so that the heat treatment will be rendered less delicate.

In General.

By the successive operations of hardening and tempering it is possible to obtain the most desirable combinations of hardness, strength, ductility and toughness inherent to the steel in question. The use of certain alloys greatly intensifies the beneficial effects derived from heat treatment. It must be borne in mind that the physical properties obtainable by heat treatment are strictly limited by the chemical composition of the steel itself. It would be impossible, for instance, to impart to low carbon steel the hardness obtainable in high carbon steel, or to make the latter as malleable as the former, or as tough as a particular alloy steel.

Photo-micrographs and data illustrating the effect of heat treatment upon the structure and physical properties of several types of steel used in aircraft construction are given in Figs. 5 to 10 inclusive. (Per cent elongation is a measure of the ductility of steel, that is, its ability to stand deformation without breaking.)

The values of tensile strength and elongation after hardening are given for purposes of comparison only. For the reasons stated, quenched steel should never be used without having been drawn.

It will be noted from the data that, as the carbon content increases, the tensile strength and hardness increase, and the ductility (per cent elongation) decreases for the steel, either in the annealed, quenched or tempered state, and the quenching temperature becomes lower.

The remarkable effect on the strength and ductility of adding 3½ per cent nickel to 0.30 per cent carbon steel is manifest, and it is plain that the effect depends almost entrely upon heat treatment.

Acid Open Hearth Process for Manufacture of Gun Steel and Fine Steel

Detailed Description of This Manner of Work, Giving the Various Steps of Manufacture—Result of Investigations Made by Special Committee as to Difficulties Encountered.

By **W. P. BARBA** and **HENRY M. HOWE**

IN Sections 1 to 11 inclusive, we give a condensed statement of our subject, in particular indicating the chief ends to be held in view in conducting the open hearth process for gun steel, while in the remainder of the paper we elaborate this matter.

1. *Composition*—In order to comply with the physical tests of American ordnance specifications, the composition of nickel steel pieces for cannon and shafting should lie within the following limits, the exact composition varying with the part of the gun which the piece in question is to form, whether tube, jacket, hoop, or other.

	Per Cent		*Per Cent*
Carbon	0.35 to 0.50	Manganese	0.50 to 0.75
Phosphorus	below 0.05	Silicon	0.15 to 0.30
Sulphur	below 0.05	Nickel	2.50 to 3.75

For ease of exposition we have assumed a specific carbon content, 0.35 per cent.

The steel should be brought at the moment of teeming† to the desired composition in every respect.

(a) The manganese and silicon must be brought to the desired proportion. In order to do this, the bath should be freed from oxygen as nearly as possible and certainly to a constant degree. This freedom from oxygen is important also for lessening or preventing segregation, blowholes, and structural metallurgical weakness.

(b) Phosphorus and sulphur must be below the prescribed limit, and to this end the stock must be sufficiently free from them.

(c) The chromium and nickel must be within the prescribed limits.

2. The *temperature* must be accurately regulated, for reasons which appear in the following paragraphs.

3. *Segregation* must be restrained, and to that end the steel must be poured at a relatively low temperature‡ and must be free from oxygen.

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*Abstract of paper presented at the New York Meeting, February, 1922, of the American Institute of Mining and Metallurgical Engineers.

†Throughout this paper *tapping* refers to pouring the steel from the furnace into the ladle, and *teeming* or *pouring* to pouring it from the ladle into the mold.

‡This represents American practice. In Section 39, we consider the reasons which favor the opposite course of pouring at a high temperature, as is done in Continental Europe.

4. *Columnar crystallization* must be restrained and the size of the dendrites kept down. To this end the teeming temperature should be relatively low.

5. *Piping Must Be Restrained*—To this end the ingots should be cast with the large end up, and at as low a temperature and as rapid a rate as the ingot sizes and the chemistry of the steel permit.

6. *External Cracking Should Be Prevented*—Here we may note that there are two periods of brittleness. First, when the steel is cooling toward the solidus, and thus is a viscous solid, an intimate mixture of a large proportion of already solid pasty particles and a relatively small proportion of still molten steel. Second, at the blue heat. The tendency in any given layer to crack in this period is often exaggerated by the simultaneous expansion which the deeper seated and slightly hotter layers are undergoing in passing through the recalescence.

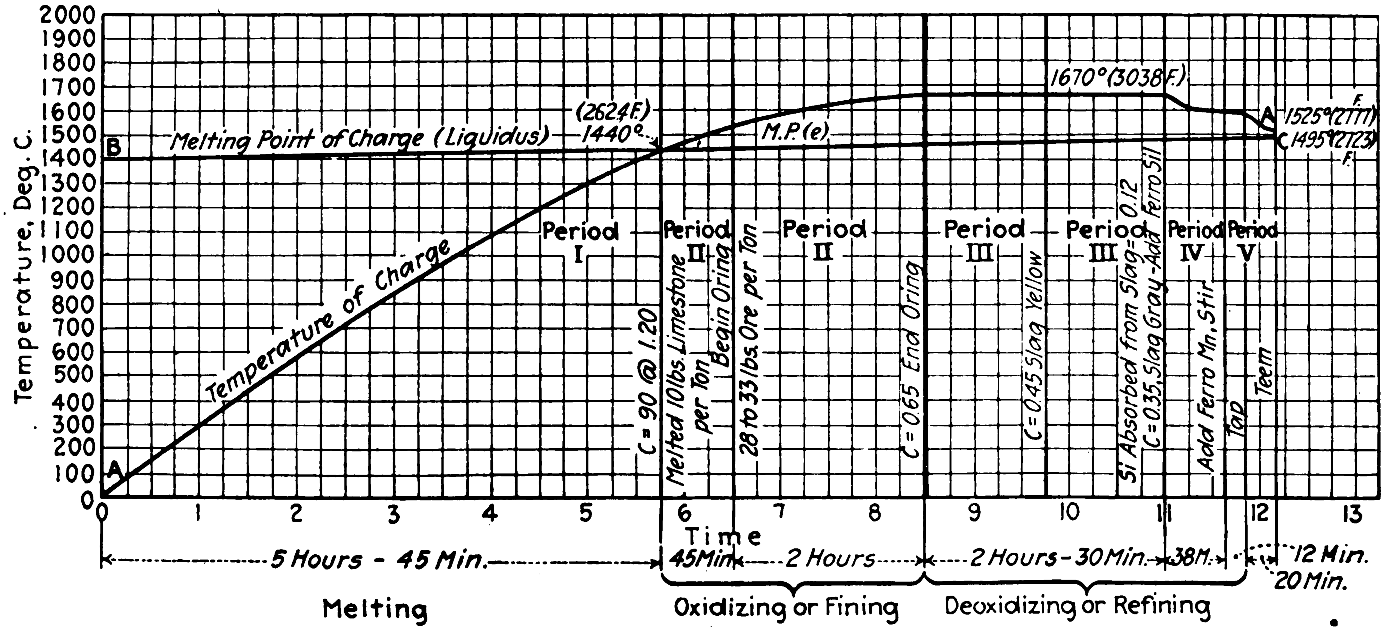

Fig. 1.

We guard against this external cracking:

(a) By tapering the mold so strongly that the ingot frees itself from it readily during the contraction period immediately after pouring, and hence is readily withdrawn.

(b) By pouring at a relatively low temperature and slowly, first so that as the molten steel rises in the mold, the thickness of the already solidified walls may increase fast enough to withstand the increasing ferrostatic pressure, and second, that the size of the columnar crystals and the dendrites may be restrained.

(c) By fluting or otherwise shaping the outer surface of the ingot, which has little power of stretching, so that it can bend horizontally and thus accommodate itself to the resistance of the slower cooling and hence slower contracting interior.

7. *Internal Cracks Including Flakes Must Be Restrained*—(a) By interrupting the relatively rapid cooling in the mold and replacing it with slower cooling in ashes as soon as the ingot has solidified sufficiently to be moved without danger of cracking. When the ingots are cast with the small end up, their molds may be stripped before they have cooled far enough to make it expedient to bury them in ashes. If this is done, the time between stripping and burying them forms a third portion of cooling.

(b) By *saddening*[§] and thereby toughening the ingot very carefully, so as to prevent cracking it mechanically in forging or rolling.

(c) By retarding the heating of the ingot for forging and that of the forgings themselves, so as to lessen the thermal stresses.

(d) By as great freedom from inclusions as possible.

8. *Retention of Inclusions Must Be Restrained*—(a) By deoxidizing the molten steel as fully as possible by means of the carbon of the pig iron, because the product of its oxidation is gaseous and escapes, whereas those of all other deoxidizing agents are solid or molten and tend to remain as inclusions. In order that as much as possible of the deoxidation should be done by carbon, the working temperature during refining must be held as high as the safety of the roof will permit.

(b) The nearly complete deoxidation by carbon should be followed by further deoxidation by silicon. The manganese should not be added till after this silicon has done its work of deoxidation, in order that as little as possible of it may oxidize. This is both so that the manganese content of the product may be as nearly constant as possible, and that as little manganese oxide as possible may form to corrode the siliceous hearth of the furnace and form inclusions of manganese silicate with the silica so eaten away. This postponement clearly tends to lessen the oxidation of manganese; first, by shortening its stay in the furnace and, second, by predeoxidizing the bath with the silicon.

(c) The steel should be held in the ladle a moderate length of time to allow the inclusions to rise to the surface, and also for the much more important purpose of permitting the finished steel to fall to the proper temperature for casting into a successful ingot.

[§] To *sadden* an ingot means to substitute strong cohesion and toughness for its initial fragility due to its having a very coarse crystalline sugar-like structure. This may be done by giving it a succession of light reductions under a hammer or press, or in a rolling mill. "Sadden" is evidently closely related to "sodden."

9. ***Hot and Cool Pouring***—American practice, which is the chief subject of this paper, may be summed up briefly as refining hot but pouring cool. We have now seen four reasons for cool pouring:

1. That it is thought to restrain segregation.
2. That it restrains the size of the dendrites.
3. That it lessens piping.
4. That it lessens or prevents external cracking.

On the other hand, it certainly favors the retention of inclusions, by shortening the time available for their rising to the surface in the ladle. Their opportunity to rise is really good only so long as the steel is completely molten. As soon as it cools to the liquidus, it ceases to be wholly molten and becomes an emulsion of an ever-increasing quantity of pasty particles of metal which have already solidified.

10. *The Furnace Itself Must Be Protected*—To the end,

(a) Its hearth should be protected from iron oxide by covering it, before charging the scrap, with about half of the pig iron used.

(b) The working temperature of the furnace must be maintained during the melting and refining periods at the highest point consistent with safety to the furnace: First, so as to shorten the melting period, during which the hearth is exposed to the attack of the iron oxide, because it is not fully covered by the molten charge; second, so as to stimulate the deoxidizing action of the carbon of the bath during the refining period.

11. *Recapitulation*—There are really only four purposes served by these various precautions, with their many subprecautions, viz.: To make the ingots:

(a) of proper and uniform composition,
(b) of proper macro- and microstructure, and
(c) sound, that is free from pipes, blowholes, cracks, and roughness, and
(d) to prolong the life of the furnace.

12. *General Course of Acid Open Hearth Process*—The foregoing sections teach that the general aim of the process is to melt and decarburize the initial charge; to remove the oxygen incidentally introduced in this decarburization; to bring the charge to a high temperature in order to favor the deoxidation; to push this deoxidation further by means of silicon; and to complete it by means of an addition of manganese sufficient both for this purpose and for leaving in the steel the manganese content required. While doing this last we lower the temperature to that suitable for teeming, taking care that the bath temperature remains so high that the manganese reaction may complete itself, and we then teem the steel into ingots free from inclusions and other mechanical defects. Thus we "refine hot but pour cool."

13. The *raw materials* of the acid open hearth process are pig iron, scrap steel, and in standard American practice a little iron ore.

The ratio of pig to scrap is usually spoken of as if these two materials formed the whole charge. Thus the 40:60 ratio refers to the use of 40 parts, by weight, of pig iron to 60 parts of scrap apart from the small quantity of ore used. This 40:60 ratio is the one assumed in this report.

This pig-scrap ratio varies widely from 100 parts of pig, as in the typical pig-and-ore or Siemens' process, to only about 10 parts as in some European practice. To this important ratio we will return in Sections 33 to 35, after fixing our ideas by considering the standard American practice. Suffice it here to say that, as the function of the ore is to oxidize the silicon and the excess of carbon over that needed in the product plus that incidentally removed in the necessarily strongly oxidizing process itself, the quantity of ore used increases with the ratio of pig to scrap, from zero in the typical French and Italian non-oring low-pig practice to the large quantity needed for carrying out the typical pig and ore process.

Not more than 10 per cent of the whole charge should be in the form of turnings, lest the rapidity and the indeterminateness with which they oxidize introduce an indeterminate quantity of iron oxide into the charge. Here, as in all other respects, the working conditions should be brought as nearly as possible to a fixed standard, because it is difficult to compensate for the results of even minor variations in procedure.

When pig iron is relatively expensive it may be replaced partly, or even wholly, as a means of introducing the needed carbon, by charcoal, anthracite, or petroleum coke, when these latter may be had sufficiently free from sulphur.

14. *Method of Charging*—Half the pig iron should be spread upon the hearth, the scrap should be placed upon this, and the other half of the pig iron on top of the scrap. The reasons for this arrangement are, first, that the hearth should be protected by a layer of pig iron from being cut by the oxygen-bearing drops of molten scrap. As this molten metal trickles down, drop by drop, over the oxidized surface of the scrap immediately beneath, it is almost certain to become strongly charged with oxide, and hence to corrode the bottom, unless this is prevented by causing it to trickle over a layer of pig iron below it. The carbon and silicon of this pig iron will, of course, react energetically with these drops of molten oxygen bearing iron, to deprive them of their oxygen.

Second, the purpose of covering the scrap with the remainder of the pig iron is to protect it from the cutting effect of the flame, which thus is utilized for oxidizing the carbon and silicon of the pig iron, instead of being employed viciously to oxidize the scrap and, thereby, to cause it to attack the hearth and poison the bath with oxides, as just indicated.

15. *Composition of Charge*—The carbon content of a charge of 40 per cent pig and 60 per cent scrap is about 2 per cent. In melting, this should fall to about 1.25 per cent.

16. *Phosphorus and Sulphur*—For gun steel, the content of these impurities should be as low as possible, hardly over 0.05 per cent of each. In the case of small ingots, less than 26 in. in diameter and weighing less than 15,000 lbs., a very slight increase in the phosphorus and sulphur content might be considered, but not in the case of large ingots, because in these the local concentration of phosphorus and sulphur, both in the axial segregate and in the interdendritic or local segregates, more easily causes a prohibitorily large content of these impurities locally, resulting in black ghost lines.

17. *Manganese*—(a) It is well that there should be from 1 to 1¼ per cent of manganese present in the initial charge. Some of this oxidizes during melting, but an appreciable amount remains in the molten metal and aids both in the removal of sulphur in the form of manganese sulphide and in lessening the oxygenation of the bath. By this latter effect, it lessens the loss of manganese in the final additions.

(b) This restriction of the oxygenation of the bath, even to the end of the process by an initial manganese content as small as 1 per cent, is surprising. The intensity of the deoxidizing conditions needed in making ferromanganese in the blast furnace shows how readily manganese oxidizes; hence we should expect the initial manganese to be oxidized rapidly during the oxidizing stages, both in melting down when the upper half of the pig iron trickles down drop by drop over the oxidized crusts of the metal beneath it in a strongly oxidizing atmosphere, and also in the intentionally oxidizing stage, Period II.

18. *Nickel*—The nickel content of the initial charge should be somewhat less than that required in the final product, so that it may be rectified by addition of nickel at a convenient stage in the process. Rectifying by the subtraction of nickel is, of course, impossible.

19. *Chromium*—Unless chromium is absolutely required by the specifications, it is advised that not more than 0.05 per cent of it should be present in the mixture, because of the difficulty of overcoming its tendency to cause inclusions and consequent laminations. Chrome steels, as such, are not discussed here.

20. *Graphical Representation*—Fig. 1 is an attempt to express the various stages of this process graphically. Vertical distances represent temperature and horizontal time. For convenience, the process may be divided into five periods as follows:

I. Melting the charge.

II. Accelerating the oxidation of the carbon in excess of that needed in the product by oring and raising the temperature to the high point needed for the ensuing deoxidation of the metal.

III. Carrying the deoxidation as far as this can be done by means of the carbon of the bath and high temperature.

IV. Carrying the dexodiation still further by adding ferrosilicon while the bath is still at a high temperature and cooling.

V. Continued cooling, adding ferromanganese, to complete the deoxidation and give the product the desired manganese content, tapping and teeming.

21. *Period I, Melting*—(a) In the first period, the liquidus BC refers to the average melting point of the charge from time to time. The melting point of the scrap is, of course, much above that of the pig iron.

(b) The more strongly curved line AA represents the actual temperature of the metal. Starting completely solid and at room temperature at the origin, it rises gradually during the first period, at the end of which it crosses line BC, so that the actual temperature of the metal coincides with its liquidus, or temperature of complete fusion.

(c) The rise of temperature should be as rapid as possible so as to shorten this period, in the early part of which hearth is attacked more or less seriously by the oxide of the melting metal which trickles down.

22. *Period II, Oring*—(a) When the charge is completely melted it should contain 0.90 to 1.20 per cent carbon. We have now to remove this carbon rapidly. The first step is to add about 10 lbs. of limestone per ton of charge, both that the slag may be fluid and that the limestone per ton of charge, both that the slag may be fluid and that the carbon dioxide given off may start the metal boiling. This boiling should continue from this point on until very near the end of the process, in order to transfer to the lower part of the charge the heat reflected from the roof against the slag floating on the metal. It has often been proved that a "quit bath" may be very heterogeneous in composition. If the circulation is not sufficiently rapid, it should be assisted chemically or mechanically. Mechanical stirring with rods is most beneficial from every point of view.

What may be called "chemical stirring" is that brought about by the evolution of carbon dioxide from the limestone and of carbon-monoxide gas within the bath itself by the reaction between the iron oxide in the slag and in the metal with the carbon of the metal. This reaction is brought about by the introduction of iron ore, or "oring."

(b) In about 45 min. after complete fusion, the charge should be so hot that we may begin oring. The quantity of ore needed is usually 28 to 33 lbs. per ton of charge and is usually added in several portions. A rich pure low-phosphorus Lake Superior hematite may well be used. The ore should not be charged before the metal has passed so far above its liquidus that there is no chance of its being locally so chilled by the ore itself, and by those features of the reaction which are endothermic, that this reaction will not take place actively. Hence the very considerable gap between lines AA and BC when the oring begins.

(c) At about 2 hr. and 45 min. from the beginning of Period II, the carbon should have fallen to about 0.65 per cent. This should bring this period to a close, because the time between the arrival of the carbon at this content (0.65 per cent) and its arrival at the final content (0.35 per cent) is only about enough to insure an approximately thorough removal from the charge of the oxygen which has incidentally been incorporated into it in this second or oring period.

23. *Period III, Deoxidizing or Refining by Carbon*—The object in this period is to carry on the removal of the oxygen from the metal by means of the carbon still present, and of the very high temperature which gives that carbon its needed energetic action on the oxygen. The observations of Doctor Burgess indicate that the temperature of the metal at this time is about 1670 deg. C., which is about as high a temperature as the metal can be brought to without endangering the roof or shortening its life unduly.

24. *Appearance of the Slag*—We have, at present, no direct means of following the removal of the oxygen from the molten metal, nor indeed do we know how much residual oxide is compatible with the needed excellence of the product. Instead we rely on the removal of iron oxide from the slag, on the principle that as the iron-oxide content of the metal falls, that of the slag decreases with it. And, in general, the iron oxide distributes itself between metal and slag in proportions tending to reach an equilibrium, the ratio of which doubtless varies with the temperature, the carbon content of the metal, and other conditions.

Fortunately, the appearance of the slag gives so close an indication of its content of ferrous oxide that the open-hearth process need not be held back to allow a direct chemical determination of that oxide to be made. This appearance may be noted in a slag cake about ¼ in. deep and 3 in. in diameter. But such cakes are seldom made, because sufficient information can be had from the thin layer of slag which adheres to the shank of the test ladle used to secure the many samples of metal required for observation during the process. The outer surface of this slag is dark brown, like that of glazed drain tiles, probably because its ferrous oxide content of the slag decreases. To the layman, it suggests rather an increasing degree of waxiness. But with this understood, we may speak of its vitreousness.

The color of the interior of the slag sample, apart from the rather constant dark brown of the crust, is, next to its vitreousness, the best indication of the large progress of deoxidation. A slag rich in iron oxide, and hence overlying a bath rich in oxygen, is dark brown to black. As the oxygen is removed from the metal and the ferrous oxide from the slag, this color grows continuously paler, to a yellow, a gray, and if the deoxidation is complete in the electric furnace, even to a white.

By the middle of Period III, when the carbon content has fallen to about 0.45 per cent, the ferrous oxide content of the slag should be reduced to about 18 or 20 per cent, and its color should be a clear pale lemon yellow in the case of a charge initially nearly free from manganese; and of a like tint, but more greenish, in the case of a charge containing initially about 1 to 1¼ per cent of manganese, as indeed is very desirable. The manganese oxide adds a strong greenish cast and sometimes a dark greenish central "streak" to the color which the ferrous oxide gives itself. In this case the ⅛ to 3/16 in. thick section of the slag sample has five differently colored layers, two dark brown outer ones, then two of the characteristic yellow, then a central darker cloudy greenish "streak," merging into the yellow ones.

25. *Period III, Continued*—In the remaining half of Period III, the continuing removal of the iron oxide is recognized by the change in the color of the slag from yellow toward gray, in case the charge contains initially 1 to 1¼ per cent of manganese. This color indicates that the ferrous oxide of the slag has been reduced to about 15 per cent, and this in turn that the metal is as thoroughly deoxidized as it can be by the action of its carbon alone. The color and the texture of the slag referred to are typical only of the average practice, and both are affected by the volume of the slag, which depends, first, on the content of silicon and manganese in the charge; second, on the rapidity with which the charge is melted; and third, on the character and composition of the bottom.

During Period III, a certain quantity of silicon is reduced from the slag by the carbon of the metal, which should now have a silicon content of about 0.12 per cent. This increase in the silicon content of the metal, at least up to 0.12 per cent, is recognized by a progressively increasing compactness of the test ingots of the metal and their freedom from gas cavities. This, in turn, is due rather to the decrease of iron oxide in the metal than directly to the increase of silicon content. It has been reported lately that the silicon content of the metal at this point, as determined by chemical analysis, may include an important quantity of silica. One of us has good evidence that, in good practice, the increase of silicon content is not merely apparent but real, and any content of silica is negligibly small.

26. *Period IV, Deoxidizing by Silicon*—(a) A sample of metal is now taken for the "go ahead" test, that is, a test ingot for a combustion determination of the carbon present in the charge. This test should show that the carbon is now about 0.35 per cent, or very close to that aimed at in the final product, so that we may safely go ahead with all preparations for tapping. To insure that the carbon in the product will be very close to that found in the "go ahead" test, we now arrest the decarburization by two distinct steps. First, at the time of drawing this, we make an addition of ferrosilicon, which will be attacked by any oxygen still present in preference to the remaining carbon. After this we decrease the temperature by lowering the damper and shutting off the air and gas, so that the only circulation through the melting chamber is due to leakage. We here act on the principle that the oxidation of the carbon is favored by a high temperature and opposed by a low one, as is well known to be true in the Bessemer process. A visible drop in temperature is shown at once by the changed appearance of the surface of the slag which, by the time the laboratory reports are received, will probably show a few dark cool points.

(b) The ferrosilicon, which may be of the 11 per cent silicon grade, is added while the temperature is still so high that it melts almost immediately and quietly, that it attacks quickly any oxides remaining, and that the resultant silicates coalesce readily, rise to the slag, and leave the bath, which becomes very quiet, and practically ceases bubbling.

(c) The cooling must not go so far as to interfere with the prompt melting of the ferromanganese in Period V, and its reducing any residual oxide. The precaution is easy to carry out successfully.

27. *Period V, Adding Ferromanganese and Tapping*—(a) At the end of about 38 min., Period IV comes to an end, and by this time the ferro-silicon should have completed, as far as it can, the deoxidation of the metal. We now charge the ferromanganese. This addition is purposely delayed until the bath is thoroughly deoxidized, in order to prevent any considerable loss of manganese, primarily in order that the small loss of manganese may testify to the thoroughness of the deoxidation caused by the action of temperature and carbon in Period IV, and secondarily because any considerable loss is likely to be an indeterminate one and thus to lead to irregularities in the composition of the product. Of this manganese, a very small quantity may be consumed in still further reducing the ferrous oxide of the metal, but most of it remains in the metal, giving it the physical qualities called for. At the end of about 12 min., the diffusion of manganese should be so complete that we may tap the charge into a ladle, in which the temperature falls still further, nearly to the liquidus. The steel is held in the ladle long enough, say 20 min. for 60-ton charges which are to be poured into very large ingots, to bring it to the relatively low temperature which is desired in American practice, as explained in Sections 37 and 38. We now teem. This brings us to the end of Period V, and therefore, to the end of the whole operation.

28. *Indications for Period V*—The reduction of the ferrous-oxide content of the slag to 15 per cent or less and the change of its color to gray at tapping time are trustworthy indications that the deoxidizing work of the process has been thoroughly done. In order that this may occur with the normal rate of decarburization, the ferrous-oxide content of the slag should have fallen at least as low as 18 per cent, and it should be yellow, when the carbon content of the metal has fallen to 0.45 per cent. These numbers refer to normal standard conditions, especially as to the weight and composition of the slag, and they may be changed materially by any one of various departures from the normal. For instance, to "run" or melt the roof seriously adds silica to the slag, and by thus diluting its iron oxide lightens its color.

But if the initial charge contains about 1 to 1.25 per cent of manganese, as is to be desired, the resultant manganous oxide of the slag affects these colors decidedly, giving them a greenish tint. Under these conditions, a proper degree of removal of ferrous oxide is indicated if the slag is greenish yellow when the carbon content of the metal has fallen to 0.45 per cent, and greenish gray at tapping time. This greenish yellow slag may contain 15 per cent or less of FeO.

29. *Loss of Manganese on Addition of Ferromanganese*—(a) A further and extremely important indication that the metal has been thoroughly deoxidized before the ferromanganese is added is given by the loss of manganese in this reaction, which should not much exceed 10 per cent of the added manganese. At some well-conducted works, after adding 0.73 per cent. of manganese to a bath containing 0.10 per cent, there is found in the ingots about 0.65 per cent, representing a loss of 0.18 per 100 of steel, or 4.61 per 100 manganese.

(b) Such inferences from the loss of manganese can be trustworthy only when the conditions in general, and in particular the time between adding the ferromanganese and determining the residual manganese, are strictly constant.

(c) If a larger proportion of the added manganese is lost, taking into account the length of time between adding ferromanganese and teeming, it is good evidence that the ferrous oxide had not been thoroughly removed from the steel. It is recommended that this point be watched with great care.

30. *Reasons for Procedure in Deoxidizing Bath of Molten Steel*—(a) At the end of the oring, Period II, the bath of molten steel is richly charged with oxygen, probably in the form of ferrous oxide FeO. and the next task is to remove this oxygen as completely as possible. This means transferring the oxygen from the ferrous oxide to one or another agent. such as carbon, silicon, and manganese, each of which in its turn becomes oxidized. The procedure should be such as to cause as much of this oxygen to be removed by carbon and as little as possible by silicon and manganese, because the oxide of carbon is gaseous and escapes spontaneously, whereas those of silicon and manganese are molten. They are liable to remain entangled in the solid metal in the form of inclusions, which weaken and embrittle it greatly.

(b) In order that as much as possible of the oxygen should be removed by the carbon, it is necessary to work at as high a temperature as possible, because the power of the carbon to combine with the oxygen increases with the temperature. Hence the temperature of the metal is raised as rapidly and as high as is consistent with safety to the roof of the furnace.

(c) As the quantity of iron oxide remaining in the bath decreases, the carbon of the bath, finding itself no longer fully occupied in deoxidizing iron oxide, attacks the silica of the slag and hearth, introducing silicon into the molten metal. By the time that this action has raised the silicon in the bath to about 0.12 per cent, the power of the carbon to remove further oxygen has become so far exhausted that the further deoxidation of the dissolved iron oxide by this carbon has become so slow that it becomes expedient to use a stronger deoxidizing agent. Our choice naturally lies between manganese and silicon.

(d) In the acid open hearth process, to which this paper refers, silicon should be used here, chiefly because the silica which it forms does not attack the hearth of the furnace as the manganous oxide resulting from the use of manganese does, forming manganese silicate.

It is true that, in careless hands, the use of silicon may cause the formation of very harmful inclusions of silica, but if the care and skill appropriate to the manufacture of cannon steel are used we believe that this danger can be avoided fully. Of course whatever deoxidizing agent we use we must provide for the removal of its oxidized products. In the case of carbon, these products escape spontaneously because they are gaseous. In the case of manganese, they escape readily because the resultant silicates of manganese are fusible over a wide range of composition, so that they coalesce easily into masses so large that they rise quickly to the surface by gravity. But the product of the oxidation of silicon, silica, is infusible by itself at the open hearth temperature. Hence should any of it remain uncombined with metallic oxides its individual particles would stay suspended as a fine emulsion and, persisting in the finished product, injure it greatly. Hence the use of silicon presupposes the presence of enough oxide of iron or manganese to form with the resultant silica a fusible and hence a coalescing product, which will remove itself freely by gravity. This is in harmony with the general procedure, using silicon for nearly but not quite the last of the deoxidation, when the resultant silica finds residual oxides to combine with, and then completing the deoxidation with manganese, the products of the oxidation of which are fusible and hence self-removing.

(e) Moreover the quantity of silica resulting from the removal of one part of oxygen from the molten metal by silicon is clearly far less than the quantity of manganese silicate resulting, first, from the oxidation of manganese to manganese oxide by that oxygen, and, second, from the formation of manganese silicate by the scouring action of the manganous oxide on the hearth.*

That manganese silicate does form, if manganese instead of silicon is added at this stage, has been proved directly by dissolving quantities of the resultant metal large enough to yield enough inclusions for chemical analysis.

(f) A welcome effect of the silicon added at this stage, when the oxygen content of the bath has become so low, is that it practically arrests the oxidation of the carbon, probably by combining by preference with that oxygen. Indeed, we now have the appearance of complete equilibruim, with no further transfer of any of the elements present from metal to slag. This arrest of the progressive oxidation of the carbon, manganese, and silicon simplifies the conduct of the process by assuring us that the content of these elements found in the "go ahead" test will persist and occur in the ingots, practically undiminished in the case of carbon, and but slightly diminished in that of manganese.

(g) Parenthetically, in operating on a basic hearth, whether that of a basic open hearth furnace, or that of a basic electric furnace, reasoning the converse of that in Section 30 (d) and (e) leads us to use manganese instead of silicon for removing the bulk of the oxygen left at the end of Period III, when the carbon has done its work of deoxidation as thoroughly as it can. The removal by silicon of the oxygen left at this stage would yield silica, which would attack the basic hearth, corroding it and thereby yielding inclusions of silicate of lime, magnesia, or whatever bases constitute the hearth. As before, the quantity of these inclusions of silica plus base, resulting from the removal by silicon of a given quantity of oxygen from the metal, would exceed the quantity of manganous oxide formed in performing that same deoxidation by means of manganese.[†] Attention should be called to recent practice where ferrosilicon is used as a preliminary addition in basic steel melting both in open hearth and in electric furnaces with basic hearths.

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*One part of oxygen would yield by the reaction $2O + Si = SiO_2$ $(2 \times 6 + 28.4) \div 2 \times 16 = 1.9$ parts of silica; whereas the reaction $O + Mn + SiO_2 = MnSiO_3$. it would yield $(55 + 28.4 + 3 \times 16) \div 16 = 8.2$ parts of manganese silicate if of that composition, or about four times as much. Indeed the difference in favor of silicon is likely to be still greater, because each molecule of manganous oxide being released in the presence of an unlimited excess of the silica of the hearth, is likely to combine with more than one molecule of that silica.

(h) Returning to the study of the acid open-hearth process, manganese in the form of ferromanganese is now added and stirred in, both to push still further the removal of oxygen from the bath and to give the metal the intended manganese content.

(i) Looking back on this deoxidation as a whole, we note first that carbon is the most desirable deoxidizing agent, because its oxides are gaseous and cannot form inclusions; second, that silicon is next in merit in acid furnaces, because it leaves less inclusions than manganese; and third, manganese is the last addition to make in such furnaces, because it is the strongest and can remove most of the remaining oxygen.

(j) Accordingly, by maintaining a very high temperature we enable the carbon to do as much as possible the work of deoxidizing. We then use silicon to do as much of the remaining deoxidation as it will; and only then do we add manganese to complete the little deoxidation still to be done, and to give the product the needed manganese content.

(k) It is interesting that the manganese silicate formed on adding ferromanganese to imperfectly deoxidized steel is more abundant in the deeper seated parts of the ingot, especially of large ones, than in the crust, probably because of the fusibility of the manganese silicate itself. In short, this silicate migrates like the segregating elements, carbon, phosphorus, and sulphur. In such steel, an excessive quantity of this silicate forms, because the abnormal quantity of oxygen present in the bath oxidizes a correspondingly great quantity of manganese to manganese oxide, which in turn dissolves from the hearth a correspondingly great quantity of silica.

This concentration of the manganese silicate in the deep-seated, and therefore last solidifying, parts may be referred jointly to segregation proper, and to the greater length of time available there for the coalescence of the manganese silicate, under the churning action of the convection currents in this imperfectly deoxidized, and hence wild, steel, into particles large enough for detection. This coalescence, though it would not affect the quantity of the manganese silicate found by chemical analysis, would increase that detected by the microscope.

31. The *use of aluminum, titanium, vanadium,* and like deoxidizers for the specific purpose of removing the last of the oxygen from the bath, as distinguished from their legitimate and growing use for introducing some of these elements as essential constituents of an alloy steel, should be discouraged. It affords so easy a way of covering up imperfect deoxidation in the normal way, chiefly by carbon, then by silicon, and last by manganese, as to form a constant temptation to slovenly working, and especially to slighting the thorough deoxidation by carbon at a prolonged high temperature. The oxide products of deoxidation by these elements are not gaseous, and hence tend to form inclusions. We do not discuss the manufacture of alloy steels other than nickel steel.

32. *Continental Low Pig Process*—Instead of using about 40 per cent of pig iron, as in the American practice just described in Sections 7 to 20, and thus having in the bath when first melted far more carbon than is needed in the product, then removing this excess of carbon with ore, and then removing the oxygen introduced by this ore, the typical French and Italian practice is to use much less pig iron, sometimes so little that the charge when first melted has only about 0.10 to 0.20 per cent more carbon than is needed in the product. In this practice, the use of ore is avoided altogether, because the slight excess of carbon present will be removed spontaneously in bringing the charge to tapping temperature, by the action of the furnace atmosphere and of the iron oxide which is taken up during melting, and distributes itself between metal and slag in proportions approaching equilibrium. Thus here, quite as in American practice, metal and slag contain iron oxide which has to be removed. Part of this removal is done by such excess of carbon as there is, but if this excess is very small, it has to be helped out by adding pig iron in some works, coke in others, and both in still others.

The pig iron is added when the carbon has fallen to about that sought in the product, and the work of deoxidation then proceeds by means of the carbon and silicon thus introduced. In some works, a second and even a third lot of pig iron is added when the carbon content again falls to the point sought.

Coke, when added, rests on the slag, and deoxidizes it directly. In some works, the slag is given a predetermined composition favoring its deoxidation, and through this the deoxidation of the metal, by additions of lime and limestone, clay, sand, and fluorspar to give fluidity.

These steps should enable us to make use of coke as an additional and very energetic remover of iron oxide. For instance, in some French works, the coke treatment is continued not only until the slag is green, but until the iron oxide has been so far removed from the metal that it hardly reacts at all on the carbon, and hence the bath is completely quiet. Even after this, the charge is held for 1 hr. at a very high temperature to allow the inclusions to rise, and the removal of the iron oxide to progress still further.

33. *Advantages and Disadvantages of Oring*—(a) Now that we have examined at length, Sections 7 to 20, the standard American high pig or oring practice, and have glanced, Section 32, at the Continental low pig or oreless practice, let us here bring together on one hand the advantages of oring, that it enables us to use a large proportion of the sometimes cheaper source of iron, pig iron; that it facilitates the process, by means of the boil which it induces; and that it increases the yield; and on the other hand its advantages of introducing into the molten bath iron oxide which must needs be thoroughly removed. Here, too, we should look at the advantage of high pig practice, that in it the slag color is a more trustworthy indication of the condition of the metal; and at its disadvantages, that in it there is a thicker blanket of slag interposed between what might be called the two working surfaces, that of the metal and that of the slag

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[†] One part of oxygen removed by the reaction $O + Mn = MnO$ would yield $(55 + 16) \div 16 = 4.4$ parts of manganese oxide, whereas if removed by the reaction $2O + Si + 3CaO = Ca_3SiO_5$ it would yield $(3 \times 40.1 + 28.4 + 5 \times 16) \div 2 \times 16 = 7$ parts of lime silicate if of that composition.

The numbers of course have no claim to precision. They are based on the assumption that tricalcic silicate results, with nearly three parts of lime to one of silica, which agrees with H. H. Campbell's analysis of basic open hearth slag. ("Manufacture and Properties of Iron and Steel," 205. 1907.)

itself, and that it works more slowly than low pig practice.

(b) It is self-evident both that oring enables us to increase the ratio of pig to scrap and that this, in and by itself, is desirable if pig iron is cheaper than scrap. In arriving at their true relative cost, we may be influenced by the existence or lack of a supply of molten pig to pour into the open hearth, by the slower working in high pig practice, and by like considerations. In American open hearth works it is rare that pig is enough cheaper than scrap to make it truly economical to use appreciably more than the 40:60 ratio, which we have advised for steel of this carbon content.

(c) A second merit of oring, and the high pig practice in which it is used, is that the oxygen of the ore, in oxidizing the excess of carbon of the charge, keeps the charge in rapid ebullition, and thus simplifies the melter's difficult task of keeping his roof within the narrow range of temperature between that needed to heat the charge hot enough through and through, and the only slightly higher temperature which would destroy the roof.

The boiling carries down into the metal and through it the heat reflected upon the upper surface of the slag from the flame and the roof, thus both heating the metal and cooling the roof. If the bath is still, this heat is in large part reflected back from the slag to the roof.

Because the difficulty of this transfer of heat from roof and flame to metal increases with the thickness of the slag layer, the boil is especially needed when there is much slag; that is, in high pig practice, in which the silica from the ore and from the oxidation of the silicon of the pig implies a correspondingly great quantity of slag. This consideration cautions us not to claim undue weight for the boil as an advantage of the high pig oring practice, remembering the obvious reply that it is this practice itself that gives the boil its importance, both for transferring the heat into the metal and for making the metal effectively accessible to chemical treatment applied to the upper surface of the slag.

(d) The oxygen of the ore, in oxidizing the carbon and silicon of the pig iron, leaves the iron with which it is initially united, by such reactions as $Fe_3O_4 + 4C = 3Fe + 4CO$. Part of the iron so left adds itself to the molten bath and so increases the yield of iron. In making fine steel, this saving is rarely of great moment in comparison with the feature of the practice which influence the quality.

(e) Turning from the merits to the disadvantages of the high pig or oring practice, the thicker blanket of slag which it implies, as shown in bath, so essential to high quality; for the oxygen strives ever to distribute itself between metal and slag in a ratio, fixed for given conditions even though varying with the conditions, so that the metal can be deoxidized only as the slag is.

Moreover, this equilibrium ratio is not between the total quantity of oxygen in metal and slag, respectively, but between the percentage of oxygen in each, so that the percentage to which the iron oxide of the slag must be lowered in order to bring about a given thoroughness of deoxidation of the metal is independent of the quantity of slag. Hence, the more slag there is the greater is the work of deoxidizing it thoroughly enough to induce a given thoroughness of deoxidation of the metal. It may be that the thoroughness regularly attainable is inversely as the quantity of the slag, a small quantity being susceptible of more thorough deoxidation than a large one.

(f) The objection which is urged strongly against oring, that which seems to have led to its exclusion from the standard French and Italian practice, is that, by introducing oxygen into the molten metal, it increases the difficulty of thorough deoxidation, and indeed lessens the practicable thoroughness of deoxidation of the metal.

These two objections (e) and (f) may well be taken together, as two aspects of a single objection. Their validity is not self-evident. To deoxidize a greater quantity of slag as thoroughly as a smaller one should indeed take longer, but it does not follow that the practicably attainable thoroughness of deoxidation is less with the larger quantity. Again, in purification of any kind, whether by washing or deoxidation, it is the last stage, the final degree of thoroughness, that calls for the technical skill. The greater the needed thoroughness of deoxidation, the stronger must be the deoxidizing conditions.

But while the validity of these objections is not self-evident, neither is their invalidity. Rather than belittle or ignore them we should diligently seek evidence as to their true weight. Such evidence should be found in the iron-oxide content of the slag, and the physical properties of the steel, in oring and in oreless practice respectively, though in this comparison it is hard to make the oring the sole variable.

The thorough purification of the metal from oxygen, both that formed in melting and any introduced as ore, needs indeed our most careful attention, as is shown by the length at which we describe it in Sections 23 to 30.

34. *Appearance of Slag in Oring and Oreless Practice*—American metallurgists have found a serious objection to low pig practice in the diminished trustworthiness of the appearance of the slag as a guide to the thoroughness of the deoxidation of the metal. The reason for this is evident. In the American practice, it is the metal itself that, through its carbon and silicon, initiates the removal of ferrous oxide. These deoxidize the ferrous oxide in the metal and thereby induce a corresponding removal of ferrous oxide from slag to metal, following the principle that this oxide always tends to distribute itself between slag and metal in an attempt to approach equilibrium. Hence the removal of iron oxide from the metal here precedes its removal from the slag, and hence a certain degree of removal of this oxide from the slag, as indicated by its color, is trustworthy evidence that the corresponding removal from the metal has already taken place.

But when we proceed by adding coke, or other form of carbon to the slag, it is in the slag that the removal of iron oxide is initiated. Only after the coke has begun removing this oxide from the slag does the iron oxide in the metal rise into the slag to replace, in part, that which the slag has just lost, in the attempt to approach an equilibrium distribution of the oxide between slag and metal. Here, then, the removal of iron oxide from the slag precedes that from the metal and may precede it materially. Thus a given thoroughness of removal of iron oxide of the slag is not such good evidence that the corresponding removal from the metal has already occurred.

A natural answer may be that a suitable time allowance should be made for this lagging of the metal behind the slag in its loss of iron oxide, and that a fuller removal of this oxide from the slag should be required when, in coke practice, the removal is initiated in the slag than in the American practice in which it is initiated in the metal.

To be accurate, even in coke practice, while the coke is initiating this removal in the slag, the carbon of the metal is also carrying it on there.

35. *Summary of Advantages and Disadvantages*—We aim rather to expose than impose practice. Now that we have seen the advantages and disadvantages of these two practices, the oring and the oreless, we may well remember that excellent as the results of our American fine-steel practice are, it has evolved under the American high pig traditions, and that there has been no fair chance to compare exhaustively and conclusively the features in which those two practices differ This is as true of the temperature differences as of those of oring. Such a comparison should be to the interest of all concerned, the public included. Each operator will reach the best results with the practice to which he is accustomed, but this does not indicate that he might not get still better results with some modification of his practice, once he is well accustomed to it.

The following numbers may serve as a nucleus for the data needed for such a comparison as we have just referred to. The physical properties called for in the first line are those required by the specifications of the United States Government for gun steel, whereas, if we are advised correctly, those of the second line are specified by some foreign governments.

American and One Foreign Specification for Cannon Steel

	Tensile strength, lb. per sq. in.	Elastic limit, lb. per sq. in.	Elongation in 2 in., per cent	Contraction of area, per cent
American ...	95,000	65,000	13	30
Foreign	92,000	57,000	14	not specified

We further understand that where an elastic limit as low as 52,800 lbs. to the square inch is accepted, provided the contraction of area is at least 26/4 per cent, the foreign practice also makes use of the impact test, but we believe that the test prescribed would not in fact reject any metal which passes the American specifications. Recently wide experimentation has been made in impact tests in addition to the foregoing, and much new light has been obtained.

Teeming, Molds, Etc.

36. *The Ladle*—A good deal of metal rich in inclusions is likely to accumulate on the very bottom of the ladle and particularly about the stopper, because the relatively cool ladle bottom cools the steel first tapped upon it, and thus thickens it, and impedes the rising of the inclusions which it contains. Therefore, the first 300 or 400 lbs. of steel which run through on raising the stopper should be poured into an old mold set

MEETING OF STEEL MANUFACTURERS.

The annual meeting of The Association of American Steel Manufacturers was held at the William Penn Hotel, Pittsburgh, Pa., February 17. This Association, which now comprises thirty-nine of the largest steel and iron manufacturing companies and corporations, was organized in 1895. It is not a trade or commercial organization but has devoted its activities to the discussion of technical questions in connection with rolling mill practices and with specifications for and inspection of steel and wrought iron products; and the cooperation with other associations and societies on such subjects, with a view to the adoption of standards of mutual benefit to the consumer and producer.

Mr. Charles L. Taylor, widely known in the steel trade, whose death occurred February 3, acted as secretary at the organization meeting of the Association and for a number of years took a keen interest in its affairs. Mr. W. A. Bostwick, who at his death February 4 was president of the International Nickel Company, was president of the Association from 1907 to 1911.

It is a coincidence that representatives of Jones & Laughlin Steel Company and Central Iron & Steel Company were president and vice president of the Association the first two years of its existence and during the past two years. Mr. Willis L. King of Jones & Laughlin Steel Company, and Mr. G. M. McCauley of Central Iron & Steel Company, were the first president, respectively. During the past two years Mr. Robert H. Irons, President of Central Iron & Steel Company, and Mr. Jesse J. Shuman, Inspecting Engineer of Jones & Laughlin Steel Company, have been president and vice president, respectively, of the Association.

The following officers were elected at the annual meeting: President, Jesse J. Shuman, Inspecting Engineer, Jones & Laughlin Steel Company; Vice President, E. F. Kenney, Metallurgical Engineer, Midvale Steel & Ordnance Company; Secretary-Treasurer, J. O. Leech, Manager Bureau of Inspection and Tests, Carnegie Steel Company.

Mr. Irons was presented with a silver after-dinner coffee service in appreciation of his services for the past two years.

MEETING OF ELECTRIC STEEL FOUNDERS' RESEARCH GROUP.

Officers and operating representatives of the Electric Steel Founders' Research Group held their last regular meeting in Milwaukee on February 6, 7 and 8. This Group was formed about two years ago for the systematic prosecution of cooperative technical work which could be directly applied in improving the manufacture of steel castings.

The idea back of this cooperation originated from the realization that the technical experts who are usually found directing the operating departments of steel foundries are prevented by immediate attention required for the disposition of routine matters, from concentrating on the investigations which could be prosecuted more effectively if they would engage the exclusive attention of one individual and if he would coordinate the technical activities of a few plants whose processes and products place the companies in the same class.

The members of the Group are the Electric Steel Co., Chicago, the Ft. Pitt Steel Casting Co., McKeesport, Pa.; the Lebanon Steel Foundry, Lebanon, Pa.; the Michigan Steel Casting Co., Detroit, and the Sivyer Steel Casting Co., Milwaukee. The Group's headquarters are at 639 Diversey Parkway, Chicago, where Major R. A. Bull, Research Director of the organization, maintains his office.

At the Milwaukee meeting reports were made by the operating heads of plants on comprehensive investigations into important foundry problems that had been delegated by the Group to the several companies. It is stated that much progress is being made through these Group investigations and that prospects for future accomplishments are most encouraging. The Group researches which were reported in detail at the Milwaukee meeting included those on the subjects of annealing, core practice, facing sands, furnace practice and pouring practice.

Arrangement of Open Hearths in Germany

The Steel-Makers of Germany Have Not Adopted Water Cooled Parts, But Use Detachable Posts—Arrangement of Gas and Air Chambers Is of Special Interest.

By **HUBERT HERMANNS**

BEFORE the war, the development of the Siemens-Martin process was based on sound principles. This was partly due to the demand for material with better mechanical and chemical properties than can be obtained by the Thomas process and partly to the demand for cast steel. On the other hand, the production of open hearth steel was limited to a certain extent by the cost, which was higher than that for Thomas iron. As long as the furnaces were charged with liquid material, the cost of production was about the same for both processes, and was not influenced materially by market conditions. But these conditions were different for open hearth operations, when pig iron and scrap had to be bought outside The difference in price for these materials, varying considerably according to market conditions, had a large influence upon the cost of production in these cases and caused the operators to watch carefully operation and production.

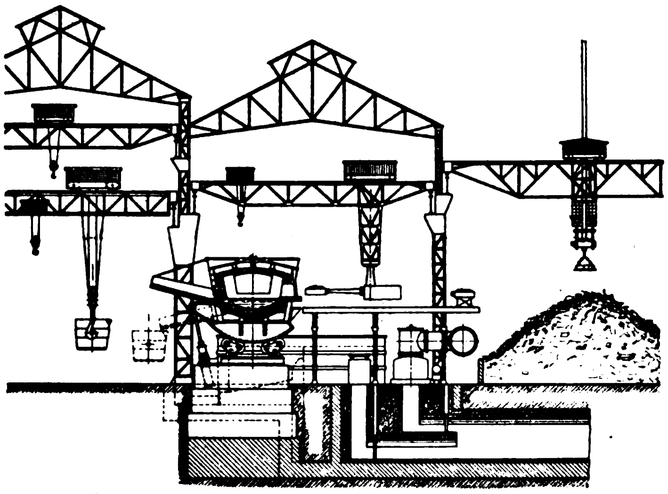

Fig. 1.

It is only natural that the, so to say, one sided requirements of the war caused a certain dislocation of the available raw materials and also a change in the quantity and quality of the finished open hearth Thomas products; the production of Thomas wrought iron had to be curtailed in the interest of the open hearth steel, because the operating forces and the raw materials had to be used as much as possible for the production of quality war material.

The Thomas process, prevailing in Germany, was based partly on the large Minette ore deposits in Lothringen and Luxemburg, and partly on the imported ores with a high percentage of phosphores or on the pig iron, made from such ore. The basic open hearth process is based chemically on the same kind of ore, but its operation is entirely different as far as working conditions are concerned. Leaving aside the consideration in regard to coal consumption, such as is necessary for the converters for driving the blowing engines and other auxiliaries and for the gas producers, the open hearth furnace has the advantage that the otherwise valueless scrap can be used, thus enabling the operator to work his furnace as economically as possible.

A decrease in the cost of production, however, can only be obtained by a highly developed design of the layout of the furnace and a most favorably developed use of the raw material. Under highly developed design of the layout of the furnace is understood not only the layout of the furnace proper, but also the best possible arrangement of the cranes, and all other auxiliaries which are necessary for an efficient working of the furnace and which are used to eliminate the human element as much as possible.

Experience has taught a general principle in regard to the layout of open hearth plants, deviations from which should only be made when local conditions demand them. Certain rules have been laid down and have been found satisfactory and which should be adhered to whenever possible. This holds good mainly for the regenerating chambers.

It was a greatly discussed question how these chambers could best be located to suit conditions. At present this question has been solved in such a respect that the chambers are arranged outside of the furnace proper. However, this arrangement requires more space and a higher first cost. The advantages obtained with such an arrangement are, first, more space on the charging and operating floor and, second, the impossibility of the slag entering the checker chambers and thus clogging them up. Slag pockets can easily be arranged, which collect the slag before it enters them.

The general description of a modern open hearth furnace is as follows: In order to strengthen the walls they are built outside in a curved form, through which arrangement sharp edges and corners are avoided. The stays and anchors of the chambers should be designed as simply as possible and the brickwork should be easily accessible. It is for this reason not a good policy to cover the outside of the chambers with a steel cover, although this is of advantage in so far as it protects the brickwork. The big disadvantage, however, connected with it is due to the fact that it is practically impossible to make repairs on the brickwork without tearing a part of the whole jacket down.

The arrangement of the charging and discharging machinery is the same as in general use in America. This arrangement has the advantage of keeping the floors clear of obstructions, and allows the charging crane to pick up the charging troughs not only on the long side of the building, but also on the short sides. With such an arrangement it is well to have the ladle crane independent of the other traveling cranes in order not to interfere with the working of the crane. All other traveling cranes should be located above the ladle crane.

Fig. 1 shows a layout of an open hearth plant which has been designed with the intention of reducing operating costs to a minimum. The plant comprises five tilting furnaces, each 38 ft. 4 in. long and 14 ft. 2 in. wide, with a capacity of 50 tons each.

It is true tilting furnaces require higher first cost, but they permit a larger tonnage and are for this reason used more extensively from year to year. The main advantage of a tilting furnace will become apparent when charging liquid material, because the same spout is used for charging and for casting. This simplifies materially the construction of the furnace and reduces the operating force.

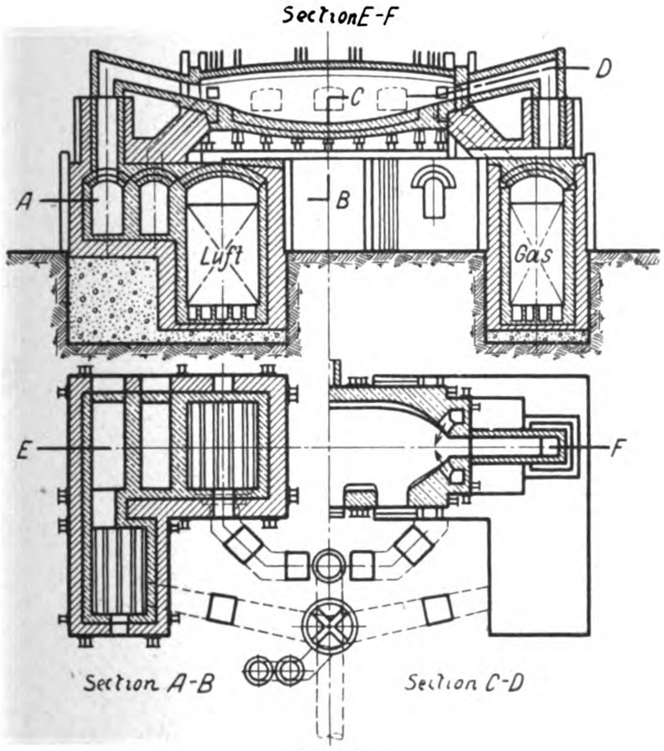

Fig. 2.

The arrangement of the charging and other traveling cranes is made in such a way that there is no machinery required on the hall floor in the front or the back of the furnaces. The scrap is taken from the railroad cars by means of magnetic cranes either to a storage place or directly to the charging molds. These charging molds are taken up by the charging cranes, swung around and emptied into the furnace. In this way all manual labor, as far as hauling the scrap proper is concerned, is eliminated. For the operation of the cranes four operators are required.

The liquid steel is taken by means of two ladle cranes and cast in four casting pits. The tilting of the ladle is done by means of a second traveler, which runs on the lower truss of the ladle crane. Another additional crane is located above the ladle crane and is operating on a higher track.

In the following a few details of modern open hearth furnaces may be shown. In the United States, water cooled parts are largely used in order to prevent the burning out of those parts of the furnace. This arrangement has not met with favor in Germany on account of the large amount of cooling water required. Here detachable posts are used. which have been found to work satisfactorily and efficiently. They allow a quick change and replacement of the burned out parts, thus saving considerable time in shutting down the furnace. With this arrangement it is not necessary to cool the whole furnace, but only the gas duct. It also allows for the building up of spare ducts, which when necessary can be installed on short notice in place of the old ones.

A furnace with detachable posts is shown in Fig. 2. The detachable parts of the uptakes and posts are entirely independent from the rest of the furnace masonry. These parts rest on the one side on the brickwork above the slag pockets, on the other side they rest against the head of the furnace. The joint between head and ports is filled with fire clay and thus made tight in a very simple manner. The whole brickwork is held together with an iron frame with hooks which allow the ports to be hauled easily with a crane. This arrangement furthermore allows a better access to the air uptakes and does away with unnecessary brickwork around those places.

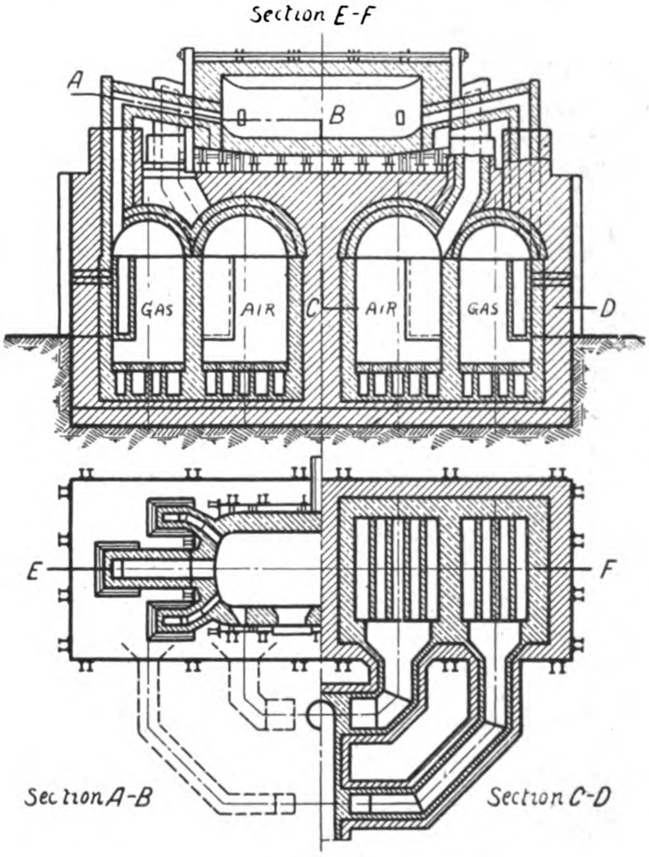

Fig. 3.

The arrangement of the gas and air chambers is of special interest. In most cases gas and air chambers are combined either directly under the furnace or outside of it. With the arrangement, shown in Fig. 2, only the gas chambers are located outside the furnace, whereas the air chambers are below it. This makes both kinds of chambers easier accessible. The slag pockets can be located behind the gas chambers below the furnace. This layout is especially advantageous in cases where for lack of space it is impossible to locate both chambers outside the furnace. The valves and the operating mechanism can be put between the two gas chambers in a way similar to the used when both chambers are outside. Another advantage is the smaller cost for the gas ducts. All this shows that the arrangement, Fig. 3, deserves the attention of the furnace designer, because it may, under certain circumstances, reduce first cost and operating cost, thus guaranteeing most satisfactory operating conditions.

As long as the furnaces are of the ordinary square shape, it is very difficult to exchange the detachable posts on account of the anchorage of the furnace. This difficulty is avoided when the furnace heads are built round, using for anchorage a sheet steel cover, which can easily be attached. This arrangement has, besides the possibility of changing the ports, a number of other advantages. The walls of the upper part of the furnace can be built of uniform thickness, thus avoiding on the one hand protruding edges in the inside of the furnace, which are easily molten away, and on the other hand too thick walls, which means a waste of refractory material. At the same time the arrangement allows an easy cooling of the furnace heads by the surrounding air, which prolongs the life of the furnace.

Fig. 3 illustrates a furnace with round head The gas uptake is made detachable in the regular way in the center line of the furnace, whereas the two air uptakes come in from the side and are also made detachable. As conditions may require, any one of the uptakes may be taken out on short notice and in a very short time, and can be replaced at once by a new one, prepared beforehand for the purpose.

Recently in many cases not only producer gas, but also coke oven gas and other high grade gases are used in the steel plants. In order to be able to use all the high grade coke oven gas, having a heating value of about 750 Btu. cu. ft. instead of using part of it in the coke oven the latter are fired with a low grade producer gas with a heating value of about 140 Btu. cu. ft. Where possible even blast furnace gas of about 100 Btu. cu. ft. can be applied instead of the producer gas.

The hydrocarbons contained in coke oven gas are decomposed at higher temperatures; they, therefore, would clog up the channels in the regenerating chambers, thus putting them out of commission in a short time. For this reason the furnaces for coke oven gas are not provided with gas chambers, but have air chambers only. This means larger air chambers in order to permit a good regulation of the temperature and to use all the waste heat. The total quantity of waste heat travels through the air chambers only. Such a furnace, when built correctly, permits the use of cold gas containing high value hydrocarbons, with the best utilization of the waste heat.

Discussion of Forge Furnaces

A Brief Practical Review of the Various Types of Forge Furnaces, Pointing Out Possibilities for Saving and Increased Efficiency with Various Classes of Fuel—Regeneration and Recuperation.

By CHARLES LONGENECKER

UNDER the heading Forge Furnaces the following types may be considered:

1st. Soaking pits.

2nd. Regenerative type furnaces — large hearth area.

3rd. Non-regenerative type furnaces—large hearth area.

4th. Furnaces of small hearth area.

The applicability of soaking pits for forging furnaces may be questioned by some but there are plants equipped with these furnaces. In some ways the soaking pit is an ideal furnace for heating steel for forging which feature will be considered more fully.

Many different modifications of the above classification can be mentioned. The first, second and third types may be equipped with waste heat boilers and the fourth type might be constructed with regenerators but such modifications would not change the type, simply modify it. The fourth type includes those furnaces heating steel for drop forging purposes and other comparatively light hammer operations. Recuperation has been applied to types three and four.

Soaking Pits.

This type of furnace is used in comparatively few plants as it is only applicable for heating ingots. At times it may be employed for a "second heat" but this is problematical. Plants having their own open hearth furnaces can install soaking pits to advantage if the tonnage is enough to justify the expenditure and if the furnaces can be kept in continuous service. The economic value of "soaking pits" is dependent on uninterrupted operation and heavy tonnage and hence these pits are not applicable to any but the largest forge plants where heavy ingots are handled. The building housing these furnaces must be constructed with regard to the work to be performed and adequate height allowed.

The fuel consumption will vary according to the temperature at which the ingots are charged. If they are charged hot as received directly from the open hearth, immediately after stripping, the fuel consumed will be exceedingly small. In fact, when the ingots are charged very hot, the "soaking pit," as the name implies, affords the opportunity for the initial heat contained in the steel, as received, to equalize. In this case no extraneous heat need be applied. This, indeed, was the original conception of the "soaking pit" as exemplified by the Djer's pit. In this form of the pit no provision was made for heating other than the heat provided by the ingots themselves. Today the same principle, somewhat modified, is practiced in the "fireless cooker." In the latter case the heat is imparted to the foods to be cooked by another object which has been heated. This source of heat radiates and the heat

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is confined and absorbed. No heat is allowed to leave the enclosure in either the "soaking pit" or the "fireless cooker" except that portion which defies retention.

When the ingots are charged hot into "soaking pits" the flow of heat in the piece (ingot in this case) is directly opposite to that which takes place in any other type of furnace charged with cold steel. In the latter form of furnace, heat is applied to the outer surface of the piece and this heat must penetrate to the centre. The flow is reversed with a hot ingot in the soaking pit. Here the molten centre must give up its heat to the surrounding metal. As to the question of segregation, piping, etc., it will be apparent that heating from the centre to circumference is an ideal method. Fissures and stresses are not so liable to form and sharp corners are not apt to be overheated as in a reheating furnace.

When cold ingots are charged the conditions there are similar to any other type of furnace as regards flow of heat. One other point of value possessed by the soaking pit is that hot ingots can be brought direct from the open hearth and placed in the pit with no danger of the ingot "bleeding" as it would do if placed in a horizontal position with the centre molten.

The fuel consumption on cold ingots varies within wide limits depending on the size ingots, etc. It may run from 300 to 500 lbs. per ton of ingots heated. With hot ingots as noted very little heat is required depending on the temperature of ingots as charged and length of time they are held in the pits.

With natural gas, oil, and powdered coal the air only is preheated while with producer gas both it and the air will be heated.

Regenerative Forge Furnaces.

This type of furnace is usually of large dimensions and consequently heats ingots or large blooms. Regeneration is applicable where the heat volume of the waste gases is large and at high temperature. There is a great divergence of opinion concerning the economy of regeneration in forge furnaces. The final analysis will disclose in every case whether the saving in fuel, and attending economies, will counterbalance the additional cost for equipment to effect regeneration. The size of the furnace practically determines what should be done. Where the tonnage to be heated is considerable and the furnace operation continuous, regeneration should be employed. The problem of regeneration is capable of solving without entering the realm of chance. Knowing the quantity of material to be heated the fuel consumption can be closely approximated from experience. With this knowledge the heat carried off by the waste gases can be determined and likewise the quantity of air required to burn the fuel. The efficiency of heat exchange is known for most forms of regenerators so that there remains only a calculation to determine the heat returnable by the air. The saving will be shown by the Btu value in heat returned to the furnace when interpreted in gallons of oil, pounds of coal, or cubic feet of gas.

The temperature carried in forge furnaces on unalloyed carbon steel, and on most alloyed steel, is high enough to give the necessary degree of heat to the waste gases. One other feature to be taken into account is the space available for the installation. A regenerative furnace occupies more space than one of the non-regenerative type and this additional space is an important factor at certain plants.

The difference in flame characteristics in a regenerative furnace as compared to one of the direct fired type is worthy of note. The principle reason for regeneration is increased efficiency which translated into dollars and cents means a very considerable saving where conditions are satisfactory for this type of furnace. The gain in heat is very easily calculated but is more apparent in actual output. The flame in a regenerative furnace is capable of closer manipulation as to oxidizing or reducing characteristics as compared to other types. Better combustion will also result from the better gas and air. Wherever powdered coal or natural gas is burned the saving is confined to the additional heat brought in by the air as it only is heated.

The heat control, as to temperature, in the renegerative type is under very close regulation, which is not so in the hand or stoker fired furnace. The change in furnace temperature cannot be so quickly made in hand fired furnaces due to the less exacting facilities for adjustment. The experienced forger desires what is generally known as a "mellow heat" and this can be more readily obtained with regeneration. The mixing of air and fuel is accomplished to a greater degree of perfection which fact eliminates to a large extent the liability for the existence of currents of unburned gas or of air. There therefore should be less oxidation as compared to other methods of firing. The labor cost will be small as the only work will be that of regulation. The fuel will be handled at a central plant and in an inexpensive manner comparatively.

In a regenerative fired furnace the fuel consumption will run approximately as follows:

Oil	per ton of output—39 gals.
Producer gas (coal)	per ton of output—450 lbs.
Powdered coal	per ton of output—400 lbs.
Natural gas	per ton of output—42,000 cu. ft.

Various types of furnaces have been built with the idea of maintaining a deep bed of fuel on the grate and operating on the semi-producer principle. The gain resulting from such furnaces is very small, if any. The sensible heat of the gas is utilized but the grate makes a poor gas producer.

Forge Furnaces—Non-Regenerative.

This type of furnace finds its field in plants where the pieces heated are not of the largest sizes, where the service is not continuous, or where the funds to be put into such equipment is limited. The latter is usually the leading consideration as the other factors are not necessarily controlling ones. It is entirely possible to heat large pieces with oil, powdered coal, or stokers with air at atmospheric temperature but it is preferable to heat the air.

By far the majority of forge furnaces are of the non-regenerative type and it is likewise true that the larger quantity of forgings are of medium or small size.

The furnaces under this heading are heated by oil, powdered coal, stokers, or hand fired. Individual stacks are the rule for carrying off the spent gases.

One of the main features in furnaces of the type under consideration, is to secure an evenly heated hearth as the hearth is long in comparison to the width. Usually there is a tendency to overheat near the bridge wall. Raising the bridge wall will help to remedy this difficulty provided sufficient space remains between the top of the bridge wall and the roof so that the heat will not be too confined in the combustion chamber.

The next feature of prime importance is to obtain

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the proper proportions for what is commonly called the "neck" and the roof directly over the neck. The neck connects the furnace proper to the stack. The "neck" must not be too large else the gases will pass out too swiftly and the furnace will be too cold at the "neck" end. If, on the other hand, the area of the neck be too small the furnace will not heat properly due to retarded combustion. There is only one way to determine the proper size of this opening and that is by experiment. Like many other problems connected with furnaces there is no formula which will apply. The Lauth furnace which met with much favor some years ago had a very steep drop in the roof directly over the "neck." The effect of this design was to increase the reverberatory effect and keep a large volume of hot gases in the furnace. The applicability of such a design will depend on the size of furnace and its service.

Another design which had quite an extensive use was the Stubblebein furnace. The object of this design was to increase the completeness of combustion by preheating the air. The rear wall of the combustion chamber was constructed so that air was drawn into openings near the base of this wall. This air passed through vertical circular passageways and entered the combustion chamber a few inches below the roof. In passing through the wall the air was heated. In the combustion chamber it met the partly oxidized gases with the result that these gases would be further oxidized. The same principle has been employed in many modifications. Any saving which might be obtained would be due to a more thorough mixing of air and gases. The preheating is open to question as the heat which is absorbed by the air is abstracted from the fire on the grate. It is hard to see where there can be enough increase in efficiency of combustion to offset the first cost and maintenance.

The coal consumption in furnaces of this type will depend on many considerations. Hand fired the coal per ton of output may run from 700 to 1,200 lbs. depending on size of furnace and amount of material heated, etc.

A furnace fired by powdered coal and heating very large pieces consumed 520 lbs. of coal per ton output. The temperature of this furnace averaged 2340 degrees F. Its efficiency was approximately 12 per cent.

Where waste heat boilers are provided the operation of the furnace, to show an appreciable saving, should be uninterrupted. There is no better means to economize heat than by a boiler but it must be kept running. Like many other engineering problems there is a point where the installation of a boiler is not economical. This will depend altogether on operating conditions. The investment when furnaces are installed with waste heat boilers is of course greater than where the boilers are left out. If the equipment stands idle the interest on the investment does not. Every plant has power conditions peculiar to itself and these must be taken into consideration.

Furnaces With Small Hearth Area.

Due to the small volume to be heated, gas, powdered coal and oil are generally employed as the heating agent in furnaces of this type. There are still a few shops where the pieces to be forged are placed on a bed of coke but such furnaces are comparatively few. There coke furnaces carry an excellent forging fire but the cost of coke and labor connected with its distribution have made this method of heating prohibitive.

Natural gas is still extensively used in some districts of Ohio and Pennsylvania but the cost of this fuel has advanced to 47c per 1,000 cu. ft. and it is being burned to a lesser extent each year.

Oil is still the predominant fuel but powdered coal is proving a strong competitor.

These small furnaces combine the heating and combustion chamber and it is vital to success that combustion be rapid. The aim must be to promote the intermixture of air and fuel and secure rapid ignition so that the heat will be generated instantaneously. The radiation from the walls of the furnace is most effective in hastening combustion. In these furnaces if the pressure is maintained and sufficiently high throughout the chamber there will be little trouble from unequal heating.

A comparative test recently run on two furnaces which will be designated No. 1 and No. 2 showed that No. 1 heated 96 pieces 2⅜ in. in diameter in 2 hours 20 minutes and consumed 32.31 gals. of oil. Thus the heating was at the rate of one piece every 1.46 minutes and the oil consumption per piece was .336 gals.

Furnace No. 2 heated 56 pieces in 2 hours and 18 minutes on an oil consumption of 30.81 gals. In this furnace one piece was heated every 2.46 minutes.

The hearth of both furnaces was 13½ in. deep by 4 ft. 1½ in. wide.

The above tests are not cited as ideal operation conditions but the performance of No. 1 furnace represents the output of a furnace which is found in many shops. The efficiencies attained by furnaces in this country are not as high as those in foreign countries which is largely due to the fact that our cheap fuels have not forced us to economize in this respect.

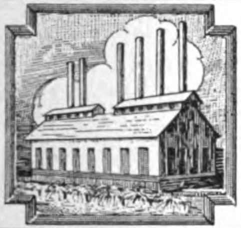
There is quite some difference in opinions relative to the rate at which steel should be heated. If heated too fast it is a well known fact, that the steel is injured by stresses which do not develop when the heating is slower. Every kind of steel has its peculiarities which will determine the rate of heating and subsequent treatment. Alloyed steels, being very sensitive to heat while the carbon steel will stand rougher usage. Experience will in the long run determine the most satisfactory forging temperature. There must be time for the necessary molecular changes to take place and this time cannot be shortened without spoiling the stock.

Probably the greatest criticism which can be offered in regard to small type furnaces is that in most instances they are too small for the work and the steel must be heated too rapidly.

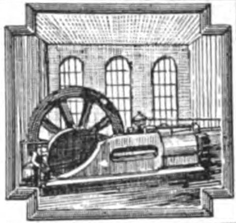
NEW OPEN HEARTH TALBOT FURNACE.

An open-hearth furnace of very large capacity has recently been developed by Mr. Benjamin Talbot, of Middlesbrough. The furnace has twin or plural hearths, connected by one or more ducts, enabling the metal to flow between, and in this way a larger volume of metal, estimated at 350-500 tons, may be treated. A central wall between the hearths overcomes the structural weakness of a single roof, heat energy being conserved, and the time for refining reduced.

A feature is the plan to tilt from the end instead of the side, and it is there where the regenerator chambers are located. The gases thus flow all in one direction, and the waste gases are carried from the tapping end of the stationary flue leading to the regenerators.



STEAM POWER DEPARTMENT



Steel Works Power Plant Management

Fixed Charges and Maintenance—Permanent Statistics for the Power Plant—Manner of Figuring Depreciation of Power House Equipment.

By ROBERT JUNE, Mechanical Engineer.

FIXED charges of the power plant are made up of a number of separate items, such as depreciation, interest on investment, rent, and administration. Maintenance consists of renewals and repairs, and the necessary labor required to make them.

Depreciation.

Depreciation results from a decrease in value of a given piece of apparatus, as a result of wear and tear, age, changing plant conditions, and changes in the art of manufacture of the particular apparatus which renders its further use inadequate. A convenient classification of the various forms of depreciation follows.

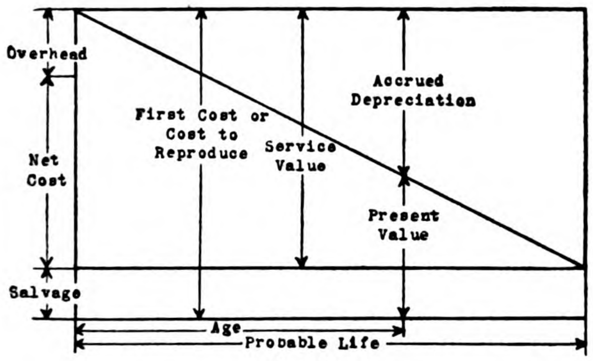


Fig. 1.

Complete Depreciation—This results from a gradual and even decrease in value, as the result of wear and tear.

Obsolescence, Inadequacy and Destruction—Marked improvements in the design of certain type of apparatus may render the use of the older type uneconomical, thus prematurely shortening its life.

Inadequacy is the result of increased demands upon capacity which renders it necessary to discontinue the use of a given machine, or the result of changing plant conditions which render the services of a machine of a given type no longer necessary.

Destruction is the result of accident. The possibilities of accident should be covered by insurance as fully as practicable. As they cannot be anticipated, it is difficult to set up a proper reserve for them. Obsolescence and inadequacy can, at times, be anticipated, and when this is the case, definite reserves should be set up to compensate for them. Whether there is reason to expect them, or not, some reserves should be set up in these days of rapid developments in the mechanical arts.

Incomplete Depreciation—This is due to unusual wear and tear of the sort which is apt to fall at irregular

TABLE I.

Approximate Useful Life of Various Portions of Steam Power Plant Equipments.

	Years
Belts	8
Boilers, water-tube	25
Boilers, fire-tube	20
Buildings, brick or concrete	40
Buildings, wooden or sheet iron	15
Chimneys, self-sustaining steel	30
Chimneys, guyed sheet-iron	10
Condensers, Jet	25
Condensers, surface	20
Coal conveyor, bucket	15
Coal conveyor, belt	10
Engines, slow-speed	25
Engines, high-speed	20
Economizers	20
Generators, direct-current	20
Generators, alternating-current	20
Heaters, open	25
Heaters, closed	20
Motors	20
Pumps	20
Piping, ordinary	12
Piping, first-class	20
Rotary converters	20
Soot blowers	8
Storage batteries	15
Stokers	12
Turbines	25
Transformers	20
Wiring	15

intervals in large amounts. Depreciation may be handled by several methods, as follows:

(1) To charge to earnings in good years and credit to depreciation reserve such amounts as the profits from operation permit.

(2) To charge to earnings the depreciation as it matures and necessitates renewals.

(3) To charge to earnings and credit to depreciation reserve annually a certain percentage of the cost determined by the average weighted life of the property.

It is quite common practice in power plant work to set up an average annual depreciation and allowance based on the original cost of the equipment, less its value as junk or salvage, and to spread this depreciation over a period of years approximating the assumed life of the equipment. Table I gives the approximate useful life of the most common type of power plant equipment, based on the assumption that they are properly handled and cared for, and that maintenance and repairs are kept up. This table does not account for obsolescence or inadequacy and its figures should be discounted on this account.

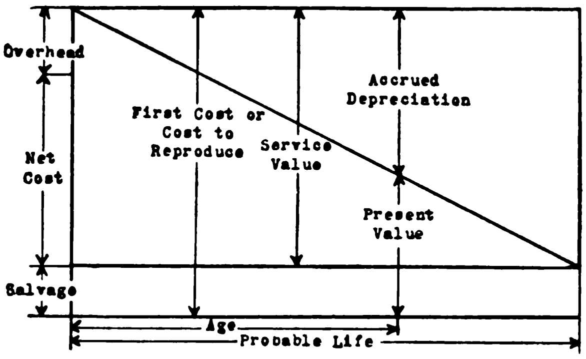


Fig. 2.

If we consider depreciation as including maintenance, we should properly set aside as a reserve a fixed percentage for the decreasing value of the equipment to represent the unmatured depreciation. In this way we equalize matters by making the depreciation allowance larger when repairs are smallest and vice versa, depreciation is smallest when repairs are largest, as the end of the useful life of the equipment approaches.

Depreciation reserves may be accumulated therefore either on the "straight-line" or "sinking fund" method.

Straight-Line Method—In the straight-line method, if we assume that the total investment, less salvage, is divided by the expected life of the equipment, we will have the amount in money which should be allowed each year to cover the accrued depreciation. This is the simplest method. It is illustrated in Figure I. Probable age of equipment may be determined from Table I with discounts as noted, to take care of obsolescence and inadequacy. In utilizing this method, the original cost is considered as including the net cost of labor and material, plus overhead, which includes insurance charges, fire and liability insurance, interest on investment during construction, installation, and, where the entire plant is being built, financial, legal and organization expenses.

Sinking Fund Method—In utilizing the sinking fund method, we set aside a fixed sum per annum which must be allowed to accumulate at compound interest. The money thus set aside, plus accumulated interest, must be equal to the original cost of the equipment, less salvage value, at the end of the assumed life of the equipment. Again we have reference to Table 1 for the life of the equipment, and again we must make proper discount for obsolescence and inadequacy.

Figure II graphically illustrates a convenient method of determining the rate of depreciation in connection with the use of the sinking fund method. Table II may conveniently be used in this connection.

TABLE II.

Rate of Depreciation.

Per Cent of First Cost.

Assumed Useful Life. Years.	Rate of Interest, per cent 4	4.5	5	5.5	6	7	8
2	49.02	48.90	48.78	48.66	48.54	48.31	48.07
3	32.03	31.87	31.72	31.56	31.41	31.10	30.80
4	23.55	23.39	23.20	23.03	22.86	22.52	22.19
5	18.46	18.28	18.10	17.19	17.73	17.40	17.04
6	15.08	14.89	14.70	14.53	14.33	13.97	13.63
7	12.66	12.46	12.28	12.09	11.91	11.15	11.20
8	10.85	10.66	10.47	10.28	10.10	9.74	9.40
9	9.45	9.26	9.07	8.88	8.70	8.34	8.00
10	8.33	8.14	7.95	7.76	7.58	7.23	6.90
11	7.41	7.22	7.04	6.86	6.68	6.33	6.00
12	6.65	6.46	6.28	6.10	5.92	5.60	5.27
13	6.01	5.83	5.64	5.47	5.29	4.96	4.65
14	5.46	5.28	5.10	4.93	4.75	4.49	4.13
15	4.99	4.81	4.63	4.46	4.29	3.97	3.68
16	4.58	4.40	4.22	4.06	3.89	3.58	3.30
17	4.22	4.04	3.87	3.70	3.54	3.24	2.95
18	3.90	3.72	3.55	3.39	3.23	2.94	2.66
19	3.61	3.44	3.27	3.11	2.96	2.67	2.47
20	3.36	3.19	3.02	2.87	2.71	2.44	2.18
25	2.40	2.24	2.09	1.95	1.82	1.58	1.36
30	1.78	1.64	1.50	1.38	1.26	1.06	0.88

Interest on Investment.

Interest on investment should cover not merely a percentage of the original net cost but it should also include overhead, such as insurance, engineering fees, office charges, cost of superintendance, interest on money paid in advance of the operation of the equipment, etc., the point being to include everything which enters into the expense of putting the equipment into service.

If the equipment, or building, in the case of a complete power plant is covered by mortgage, or bond issue, the interest rate must be high enough to include the complete interest on the mortgage, or bond, as well as any differential between the total gross cost and the amount of the bond or mortgage.

If the new equipment or building is paid for out of surplus previously earned in the business, interest should be charged at the rate which the money would earn if invested in other branches of the business or which it would earn if placed out at interest.

At this point, it is well to draw a distinction between repairs and renewals on one hand, and additions on the other. Repairs and renewals which do not increase the value or efficiency of the equipment beyond its former value must be charged to operating expenses. Additions, such as accessories which increase the value of the equipment, should be considered as capital investment. In the case of obsolescence or inadequacy, which has not been anticipated or entirely charged off in former years, only that portion of the cost of replacement above the cost of renewal of the old equipment should be charged to capital value. The remaining depreciation which has not been anticipated, must be charged to operating costs.

It should also be remembered that as depreciation occurs capital value declines, so that the amount of interest set aside each year will be less as time goes on.

Insurance.

Three classes of insurance are usually required in the power plant. First, on building; second, on equipment; and the third, liability insurance, on employees. On the first two classes, the premium is in direct relation to the value of the plant and equipment. The premium on the third class bears no relation to the cost of physical equipment, being based on the cost of labor and the hazards of employment.

Property Insurance — The relative premium on building insurance remains approximately the same year after year. However, it is extremely important to remember that when additions or alterations are made to the plant, that additional insurance should be provided. Changing replacement values of plant and equipment should also be taken into consideration. Thus, a building erected in 1912, for example, of good construction and with an estimated life of 40 years, would in 1920, if building costs had remained the same as in 1922, be properly insured for three-fourths of its original cost. However, as building costs have approximately doubled in the past ten years, the insurance should be based on the replacement cost today, less depreciation which would mean that the building should be insured at 1½ times its original cost.

<table>
<tr><td colspan="3">Description</td><td>Rate per hr.</td><td>Total hr.</td><td colspan="2">Amount $</td><td>Remarks</td></tr>
<tr><td colspan="3">Asst. Engrs.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Oilers</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Firemen</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Coal Passers</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Watchmen</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Other help</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Total Gross Labor Cost (A) $</td></tr>
<tr><td colspan="8">Deductions for Maintenance to Power House Equipment</td></tr>
<tr><td colspan="2">Description of Work</td><td rowspan="2">Name of workman</td><td rowspan="2">Rate per hr.</td><td rowspan="2">Total hr.</td><td colspan="2" rowspan="2">Amount $</td><td rowspan="5"></td></tr>
<tr><td>Name or No. of Equip.</td><td rowspan="2">Kind of Work done. State Whether Repair or Renewal</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Total Deduction for Power House Maintenance (B)</td><td>$</td><td></td></tr>
<tr><td colspan="7"></td></tr>
<tr><td colspan="8">Deductions for Construction and Repairs not for Power House</td></tr>
<tr><td colspan="2">Description of work</td><td rowspan="2">Name of workman</td><td rowspan="2">Rate per hr.</td><td rowspan="2">Total hr.</td><td colspan="2" rowspan="2">Amount $</td><td rowspan="6"></td></tr>
<tr><td>Location</td><td>Kind</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Total Deductions for Out of Power House Labor (C)</td><td>$</td><td></td></tr>
<tr><td colspan="5">Grand total deductions for labor for non-operating purposes (B + C)</td><td>$</td><td></td></tr>
<tr><td colspan="5">Net labor attendance costs A-(B + C)</td><td>$</td><td></td></tr>
</table>

DAILY REPORT SHEET FOR POWER PLANT LABOR

Fig. 3.

Changing hazards must also be taken into account. If the fire hazard increases, the insurance companies will be found to be very prompt to cancel the policies in force and place in effect new ones at higher premiums. Should the fire hazard decrease, the owner should have the old policies cancelled and new ones issued, based on the lessened risk.

Equipment Insurance—Equipment insurance should be based on replacement value just as in the case of building insurance. If old machinery is replaced by new the policy should be revised to take this new value into consideration in order to secure adequate protection.

Liability Insurance—Liability insurance has come to assume a very important place in power plant costs. The premium, as a rule, is based on the pay roll, being divided however into a number of sections, each carrying a different premium depending upon the hazards of the individual class of work. As the premium may run anywhere from one to ten per cent of the actual cost of labor it forms a very important item and should not be neglected.

The first point is to ascertain the exact amount of time put in by the various power plant employees on various classes of work, bearing different premiums. For this purpose a daily report similar to that shown in Figure III is desirable. This, in addition to serving as a check on insurance premiums, may also be used for purposes of efficiency study in order to determine whether any undue proportion of time is being put in on certain classes of work.

In going into the various classes of insurance in detail, our purpose is to point out that insurance is much more of a variable than is generally supposed and that the insurance costs for a given period should not be assumed to be in definite relation to the first cost of equipment or in definite relation to liability but that they should be ascertained exactly for the period covered by the cost analysis.

Building and equipment insurance is, of course, a fixed charge. Liability insurance is sometimes considered a part of the cost of labor and is simply added thereto as an operating expense. However, it is more simple to regard liability insurance as a fixed charge.

Rent.

The value of the ground on which the power plant is built determines the amount to be charged up to rent. Where the power plant is merely one of a group of buildings, as in the case of a factory power plant, the rental should be in proportion to the amount of ground occupied by the power plant, coal pile, etc., as compared to the other buildings. Where the power plant stands alone as in the case of a central station, the value of the entire real estate is based for rental charge. Here again we have to take into consideration changing real estate values. However, adjustment and rental charges need ordinarily be made not oftener than once a year.

Administration Expenses.

This covers such items as salaries of officers, clerical wages, office supplies, office rent, interest and depreciation on equipment, depreciation and repairs on office equipment, insurance on office equipment, postage and stationery, telephone and telegraph, legal expenses, and where power is sold as well, advertising and sales expenses. In the case of a central station, all of the above items must be charged against the cost of producing power. If the central station has other lines of activity, they must be proportioned in relation to the expenses incurred by the various departments of the business.

FIGURE IV.

Fixed Charges—

Type of Equipment...
Plant No..................Building No...
Location ....
Manufactured by...
Address ....
Date installed.................................By whom...
Brickwork and foundation put in by.. Date..............................

COST OF FOUNDATION ....
COST OF SETTING ....
COST OF BOILER ....
COST OF INSTALLATION ....

	Total Investment to Date	Interest on Investment at % Annually	Depreciation at % Annually	Rent (Based on proportionate space in building occupied by each machine)	Overhead (Based on proportionate share of taxes, insurance, office expenses, etc., for each machine	Total Annual Fixed Charges
Total Original Investment						

ADDITIONS
(Do not charge wages of regular plant attendants whose time would go on anyway, against additions)

Date	Character	Material furnished by	Cost	Labor by	Cost	Total Investment to Date	Interest on Investment at % Annually	Depreciation at % Annually	Rent	Overhead	Total Annual Fixed Charges

In the case of a factory power plant, power becomes a production expense and the overhead charged against the power plant should be in relation to the total investment, and also to the total labor expenses in the factory and the total labor expenses in the power plant.

With uniform production, administration expenses will ordinarily vary but slightly from month to month. It should be ascertained each month and figured into the cost of power. Right at this point, the writer enters the plea that the men in actual charge of the production of power be regularly supplied each month with a statement from the accounting department showing all the charges set up against the power plant for interest, depreciation, insurance, rent, administration expenses and maintenance. These figures are all too commonly regarded as a secret. Just why this is so is not clear. The figures are usually of not the slightest value or interest to any one outside the plant nor would their possession by the operating men embarrass the management in 99 plants out of 100. Giving the operating men these figures indicates first, confidence in the integrity of the men and secondly, confidence in their ability to suggest ways and means of reducing some of these charges. Finally, it tends to curtail waste and extravagance, where such exist.

Figure IV indicates a form of record which should be kept in the power plant, one sheet for each important piece of equipment. This is not a formal accounting record—its purpose is to keep the men in charge of power plant operations fully informed of the nature and extent of the investment and the various types of equipment, and the cost of operating each individual unit. Its value will depend upon the individual men and their interest in their work.

FIGURE V.

Maintenance Cost Record.

Type of Equipment.........................
Plant No...........Building No.............
Location ....
Manufactured by...
Address ....
Name and Address to call for repairs.........................
Date installed................ By whom.....................
Brickwork put in by...

Repairs.

(Do not charge wages of regular plant attendants, whose time would go on anyway, against repairs)

Date	Character	Material Furnished by	Cost	Labor	Cost	Total cost repairs to date

Maintenance.

Maintenance and repair cost records should also be kept in the power plant. Again, this is not for formal accounting purposes. Its value to the operating men is to tell them where they are at with respect to the cost maintenance of various types of equipment. Maintenance, of course, refers to the expense of keeping the plant in running order over and above the cost of attendance. It does not refer to the replacement of new units but it includes the cost of repair parts and the cost of labor over and above that of keeping plant attendance, whose time would go on anyway whether they were engaged on repair work or not.

Figure V offers in convenient form a means of keeping track of the maintenance costs in the power plant. One of these sheets should be used for each machine of any size and the accounting department instructed to place at the disposal of the operating men any needed information regarding the costs, which will enable them to keep these records with approximate accuracy.

RECENT BOOKS OF INTEREST TO BLAST FURNACE OPERATORS.

By E. H. M'Clelland

Technology Librarian, Carnegie Library of Pittsburgh

Rate of Driving.

Greenwood, William Henry—Iron: its sources, properties, and manufacture, with numerous engravings and diagrams; revised and partly rewritten by A. H. Sexton. 225 p. 1907. Cassell.

Deals with the output of the furnace on p. 158-159.

Johnson, J. E., Jr.—Commercial considerations concerning the blast furnace. 1916. (In Metallurgical and chemical engineering, v. 15, p. 235-244.)

Considers on p. 237-238 the most economical rate of driving for furnaces and the effect of the rate of driving on profits. This article is the same as Chapter XIX of "Principles, operation and products of the blast furnace" by this author.

Johnson, J. E., Jr.—Principles, operation and products of the blast furnace. 551 p. 1918. McGraw.

Chapter XIII. "The rate of driving the furnace," p. 302-313. The most economical rate of driving for furnaces and the effect of rate of driving on profits are treated on p. 512-515.

Johnson, J. E., Jr.—Rate of driving the blast furnace. 1916. (In Metallurgical and chemical engineering, v. 15, p. 21-26.)

Discussion of the best rate of driving, giving consideration especially to the effects upon the regularity of the settling of the charge, fuel consumption, power required for blowing, flue dust lost, and the life of the lining. This article is the same as Chapter XIII of "Principles, operation and products of the blast furnace" by this author.

Turner, Thomas—Metallurgy of iron. 486 p. 1915. C. Griffin.

Gives brief consideration (on p. 125) to the rate of driving of a blast furnace.

See also "Brassert," below.

Volume and Pressure of Blast.

Brassert, Hermann A.—Modern American blast furnace practice. 1914. (In Year book of the American Iron and Steel Institute, 1914. p. 15-69.)

Discussion, p. 70-113.

Says on p. 54, that "uniform practice demands that the blowing engines be so governed as to deliver a constant quantity of air and not to maintain a constant pressure." Pays some attention to rate of driving furnace under "Operation."

Grosswendt, Carl—Turbo blower and compressor regulators. 1916. (In Blast Furnace and Steel Plant, 1916, p. 426-428.)

Supplementary to preceding article. "Deals with the devices that bring about the desired results."

Grosswendt, Carl—Regulating turbo blowers on compressors. 1916. (In Blast Furnace and Steel Plant, 1916, p. 76-78.)

Discusses "means for obtaining specified operating conditions under varying handicaps."

Loewenstein, L. C.—Volume regulator for blast furnace engines. 1917. (In Transactions of the American Society of Mechanical Engineers, v. 39, p. 843-882.)

Discussion, p. 882-884.

The same, condensed. 1918. (In Journal of the American Society of Mechanical Engineers, v. 40, p. 224-233.)

Deals with the use of a constant volume governor and a volume corrector to take account of variations in atmospheric conditions.

Marks, Lionel S., ed.—Mechanical engineers' handbook. 1836 p. 1916. McGraw.

Gives on p. 1530-1531 brief consideration to the advantages of the centrifugal compressor, and its application with a constant-volume governor to blast furnace work. Describes two kinds of constant-volume governors for blast furnace purposes on p. 1539-1540.

Rice, Richard H., and Moss, Sanford A.—Blast furnace and steel mill power plants. 1917. (In Proceedings of the Engineers' Society of Western Pennsylvania, v. 33, p. 81-115.)

Discussion, p. 115-130.

Devoted to the use of the turbo-blower for blast furnace work. Includes a description of a constant-volume governor and a "volume corrector" to take account of variations in atmospheric conditions, manufactured by the General Electric Company.

Rice, Richard H.—Turbo blowers for blast furnace blowing. 1914. (In Transactions of the American Institute of Mining Engineers, v. 50, p. 104-126.)

Discussion, p. 126-142.

Includes a description of a constant-volume governor.

Smoot, C. H.—Air-volume regulation in smelting and refining furnaces. 1919. (In Engineering and Mining Journal, v. 107, p. 654-656.)

Description of author's regulating apparatus for obtaining a constant volume of air in blast furnaces. Says it has always been customary to operate iron blast furnaces with a constant volume of air.

SULPHUR IN COKE

The general problem of decreasing the sulphur in metallurgical coke and devising desulphurization processes demands that some knowledge be had of just how the sulphur in coke occurs. Unfortunately this is not known and has led to several futile attempts to determine in what form the sulphur occurs in coke. A new method of attack has been outlined by the Bureau of Mines which promises to gve much more information on this subject. This method makes use of the passage of hydrogen through the hot coke, thereby giving a means for measuring the dissociation pressure of the carbon-sulphur combination. Application of the phase rule to these results will indicate whether the sulphur is present as a compound, a solid solution, or adsorbed. The results so far obtained by the Bureau of Mines seem to indicate the presence of a compound, but further work will be required to substantiate this and study its properties.

PRODUCTION TOPICS

STRUCTURAL STEEL—IT'S PAST AND FUTURE.

By George H. Danforth

Steel construction, as it exists today, is the heir of that period, prior to the Civil War, which saw the rise and development of the structural uses of wrought iron for bridges also, to a much more limited extent, for certain forms of building work. In England both wrought and cast iron were used in construction much earlier than this but in this country, the abundant supplies of timber and the imperative need of building cheaply, delayed our use of metal to a later date. It was during this period that the theoretical work was done whereby we were taught the analysis of structures and the stresses that come from various types and conditions of loading, material to resist these stresses being proportioned in different ways to suit the ideas or whims of the designer. You have only to look over some of the early handbooks and treatises to see how our predecessors labored to find the best and most economical way, according to their lights, to solve their problems and make their structures safe. The patent office was full of the efforts of these men for at that time, the idea was rampant that the patent was the thing to protect their ideas. Few of the structures of this period remain to tell tale, having been superseded in the course of time. It is to this time that the man and the Whipple truss belong, also the Post truss, now all practically extinct. The Pratt truss is still with us but the rest have gone. Once in a while there will appear a man with a patent on some structural design that he thinks is new and valuable, but nine times out of ten, it will be found on analysis, that the new patent is but one of these old ideas that have been so dressed up by the skillful patent attorney as to get by the patent office examiner.

The great expansion of the railroads after the Civil War, was the cause of the growth of many shops for metal construction work. Some of these shops have been originally built for the making of "combination" bridges, as they were called, having wood for top chord and posts and with iron rods for tension members. The injunction of the wood and iron members being usually made by means of a casting. It was but natural that these shops should develop and multiply as wrought iron became cheaper and as the loadings became heavier. The directing minds of these shops became eventually, the designers and fabricators of the all metal bridge, as well as the occasional metal trainshed. At this time, there was little doing in the way of metal buildings of any other type. The first extensive use of metal skeletons in the ordinary commercial building was made when part of the Western Union Building in Chicago was constructed. This was followed in 1883 by the Home Insurance Bldg., also in Chicago, where the first Bessemer steel beams were used, in connection with cast iron columns to form a complete frame. It is well to stop a moment and think how recently steel construction has developed when you are trying to form an idea to what it's use may be in the future.

In considering this future, it should be borne in mind, that it is only within a few years, that there has been any real rival to steel as a construction element in structures of any size. Wood has been displaced on account of lack of strength and high cost. For certain types of factory construction, known as mill construction, it is still favorably regarded but the high cost and tendency to dry rot is crowding it out, even there, and relegating its use to ordinary house construction where loadings are light and poor grades can be used. Even here, its combustibility is against it. The growing idea that construction shall be incombustible, if not fireproof, is practically certain to cause its abandonment; except for the finish or for temporary structures, where ease of making connections and re-use of the material after the structure is abandoned, make its use advisable.

Concrete has been used of late years, to a considerable extent, and has had many enthusiastic advocates. In fact, its standing today has been more than impaired by this very enthusiasm, causing it to be used in places where it has really had no business to be even considered. Compared to structural steel, it is heavy, and cumbersome and if it is to displace structural steel there will have to be ways found to insure its standing the weather, at least in this climate. The tendency of concrete to spall under heat is also against it. To spall, when used as an insulator against fire is bad enough, but when the spalling is from the very member on which you are depending for the strength of your structure, it is fatal. There is also the very serious objection to be urged, that it is subject to all the incidental defects involved in field work with no means of knowing what you have until it is in structure. You cannot test it beforehand to determine what you are going to get as a finished result.

Terra-cotta has been brought forward by some and quite a number of good sized arches and domes have been built, but so far they seem to have defied analysis and are constructed on emperical rules, the use of this material for anything aside from the few places where it serves a special purpose is hardly possible.

So far nothing has been developed that would indicate that the use of steel for "structural purposes" was on the wane, or that we are likely to see it displaced in the immediate future. Comparatively speaking, it is light in weight for the strength it possesses; there is no question as to determining its quality before it is incorporated into the structure or as to how it is connected after you get it there. It is not fireproof but it is combustible and if the use is such, that protection from fire is necessary, such protection can be readily applied. As made at the present day, it has to be admitted, that it will rust, when subjected to certain exposures, and as a protection against this we have been relying on various paints and coatings. It is not logical to have as the only protection against corrosion of a structure, costing many thousands of dollars, a microscopically thin film of oxidized vegetable oil or something that is equally tender and fragile. Some day there is no doubt but that we will produce a non-corroding steel, that will be commercially available for construction purposes and then the use of paint will be relegated to its proper sphere, that of finish and color only, and not then if we think the natural appearance preferable.

With the rise of structural steel, there developed a mania

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*Abstract of paper presented at Engineering Society of Western Pennsylvania.

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PRODUCTION TOPICS

for diverse specifications both for quality of the material and for workmanship on the completed structure. Every railroad and nearly every engineer had its own, and from their view-point the only right and proper one. This led to endless confusion, with their minute variations, an impossible situation from a production stand point, was created. We still have plenty of specifications of various tendencies, but thanks to the labors of some of our engineering and other technical societies, they are getting to be more reasonable and for similar types of structures, they are also getting to be more uniform. There is still room for further progress in this direction and it is to be hoped that the time is not far distant when the specifications for quality will be reduced to one for each, of not more, than say, three or four types of structures. It is for work of this character, that many of these Societies are to be most highly praised. Workmanship specifications have to a large extent grown more rigid as the years have gone by. Punched holes, originally universal, have been barred under certain conditions and reamed holes or holes drilled from the solid have been called for in high class work. These constitute a serious item to be considered. There seems to be a tendency, however of late, at least in some quarters, to let up in this regard, as if it were considered that the results obtained, were not worth the extra expense. The same can also be considered true of the epidemic of sand-blasting, and later of pickling to remove mill scale, that for a time ran rampant in certain places. Possibly the absence of easy money among our railroads and their need of getting value received, may have had something to do with this change.

PHYSICAL TESTING OF COKE.

The physical characteristics of coke is a matter of great importance to the blast furnace and foundry men. Tentative definitions of terms relating to coke have been formulated by the Bureau of Mines and submitted to the American Society for Testing Materials. Data are being assembled as to the methods in general use in making "shatter" and "hardness" tests on coke. The Bureau of Mines realizes that if the results of such empirical tests are to be used to the best advantage they must be standardized in order that the results obtained be comparable. It is proposed to get as much information together as possible as to the methods of conducting these tests and from these data tentative methods will be submitted to the American Society for Testing Materials for the making of "shatter" and "hardness tests on coke.

TRENT PROCESS FOR CLEANING COAL.

The efficiency of the Trent process in cleaning coal has been determined by the Bureau of Mines for typical coals of the United States. The point of superiority of the Trent Process over ordinary washing methods is the high combustible recovery obtained, in some cases as high as 99 per cent. Low-grade sub-bituminous coals and lignites do not respond readily to treatment by the process. The process is not efficient in removing sulphur present as pyrite in the bituminous coals; with anthracite coals, sulphur removal is good. The relation betwen fineness of grinding and ash separation has been determined on typical coals pulverized to sizes as small as 10 microns, (.01 mm).

JANUARY FABRICATED STEEL BUSINESS RELATIVELY GOOD.

In January 72,100 tons of fabricated structural steel work was contracted for throughout the United States, against 71,500 tons in December and 63,000 tons the monthly average for 1921. In January, 1921, the total was only 32,000 tons, but in January, 1920, it was 135,000 tons. Taking into account the hesitation evident in consummating investment enterprises, the fact that January is slightly better in tonnage than December may be significant. In the last ten years January has always shown a falling off from December with two exceptions, 1913 and 1914. January bookings for a decade have averaged 82,800 tons, while December bookings have averaged 111,200 tons. Thus January is about 15 per cent better than the 1921 rate and not quite 13 per cent under the January rate. February has normally been 10 per cent better than January.

The statistics of the volume of business taken by the bridge and structural shops of the country are those of George E. Gifford, secretary of the Bridge Builders and Structural Society, 50 Church Street, New York. The January business indicates that 40 per cent of shop capacity was covered, the total monthly capacity being put at 180,000 tons.

HUMAN ELEMENT IN ENGINEERING.

The feature of the regular monthly meeting of the Engineers' Society of Western Pennsylvania, held in the Georgian room, William Penn hotel, Pittsburgh, Tuesday, February 21, at 8 P. M., was the presentation of a paper on the "Human Element in Engineering" by E. Atkin Starks, General Sales Manager of the Duravla Mfg. Co., New York. Mr. Starks stressed the importance of giving due consideration to the relations with employes in all engineering projects.

STEEL TREATERS MEETING.

To more directly serve members of the American Society for Steel Treating, sectional meetings have been instituted, the first of which will be held at the McAlpin Hotel, New York, March 3. Fourteen of the eastern and New England chapters will participate in this meeting. A variety of subjects will be discussed in the seven addresses which are scheduled. Attendance is not limited to members. The complete program follows:

11:00 P. M.—Registration.

1:30 P. M.—Address of welcome.

2:00 P. M.—Addresses: "Cold Headed Bolts — Their Metallography and Heat Treatment," illustrated, by V. E. Hillman ,Crompton & Knowles Loom Works, Worcester, Mass.; "New Developments on the Influence of Mass in Heat Treatment," by E. J. Janitzky, Illinois Steel Co., South Chicago, Ill.; "The Magnetic Testing of Small Case-hardened Chain," by A. V. DeForest, American Chain Co., Bridgeport. "Stainless Steel in Cutlery Use," illustrated, by F. G. Hall, R. Wallace & Sons Mfg. Co., Wallingford, Conn.; "Calite—A New Heat Resisting Alloy," illustrated, by G. R. Brophy, General Electric Co., Schenectady, N. Y.

6:00 P. M.—Informal dinner.

8:00 P. M.—Addresses: "Perfecting a Drop Forging," illustrated by J. H. G. Williams, Hartford, Conn.; "The Manufacture of Steel," illustrated, by B. H. Long, Carpenter Steel Co., Reading, Pa.

NEWS OF THE PLANTS

The Wallingford Steel Company, Wallingford, Conn., recently organized under state laws with a capital of $200,000, has acquired property near the end of Valley Street, on the east side of the Quinnipiac River, Wallingford, as a site for the erection of a new plant for the manufacture of rolled and other steel products. The initial works, plans for which are being prepared, will comprise three buildings, 100x130 feet, 100x300 feet, and 50x100 feet, all one-story. One of these structures will be equipped as a rolling mill. Ground will be broken at an early date. The company is headed by C. W. Leavenworth, F. A. Wallace and E. B. Cleborne, all of Wallingford.

The Evansville Structural Supply Company, Evansville, Ind., manufacturer of iron and steel products, is planning for the erection of a new steel fabricating plant, to be one-story, 100x200 feet, and estimated to cost approximately $40,000. The company is now operating a works at 215 First Avenue. Construction of the new plant will be commenced at an early date.

The Carnegie Steel Company, Pittsburgh, Pa., has work under way on the rebuilding of the blast furnace No. 4, at its Lorain, Ohio, works, and will have the structure ready for service at an early date. The company is also making extensions and improvements in its slag crushing plant at this location, and will install new finishing machinery in certain departments at the mill.

The Wheeling Steel Corporation, Wheeling, W. Va., has awarded contracts for the erection of a number of additions to its plants at Steubenville and Portsmouth, Ohio, for extensive increased capacity, and different features of the work will be inaugurated at once. At the Portsmouth mill, a new rod and wire plant will be constructed, the first noted to be equipped with a continuous rod mill of special design. In the wire-working department, the installation will include machinery for general wire-drawing, fence and nail production. New pickling, annealing and galvanizing machinery will be installed in these different branches of the works. A large boiler plant will be constructed, as well as a new gas producer department. New rolling mill machinery has been installed at the Steubenville plant, and still further expansion will be continued in this direction. New tables and transfers, shears, intensifiers and auxiliary operating equipment has been ordered, with an eight-stand, 19-inch continuous bar mill. A 35-inch blooming mill will also form part of the new equipment. Plans are under way for the erection of a new boiler plant at the Steubenville works, and at a later date it is proposed to install a complete new electric generating plant, provided with turbo-generators as prime movers to furnish all electric power required for the works. A new gas producer will be installed, utilizing space now given over to one of the skelp mills. A new storehouse and greater yard facilities will form a feature of the improvement work under way, and about 10 new electric traveling cranes will be installed, including two 150-ton ladle cranes. The entire program for the two plants calls for an expenditure approximating $5,000,000.

The Direct Steel Process Company, San Jose, Cal., now operating a temporary plant at Alameda, Cal., is planning for the erection of a new steel works in the vicinity of San Francisco, Cal., and is negotiating with the Chamber of Commerce at the latter place for a suitable site. It is proposed to commence work at an early date. H. Bardue, vice-president and general manager of the company, is in charge of the project.

The Maryland Steel Rolling Company, 1410 Fidelity Building, Baltimore, Md., has taken title to property at St. Helena, near Baltimore, for the erection of a new plant for the manufacture of steel bars and kindred products. Plans have been completed for a main building, 65x228 feet, with a number of smaller structures, and work will be commenced at an early date. A number of contracts are being placed for equipment, including a traveling crane. R. S. Baldwin, general manager is in charge.

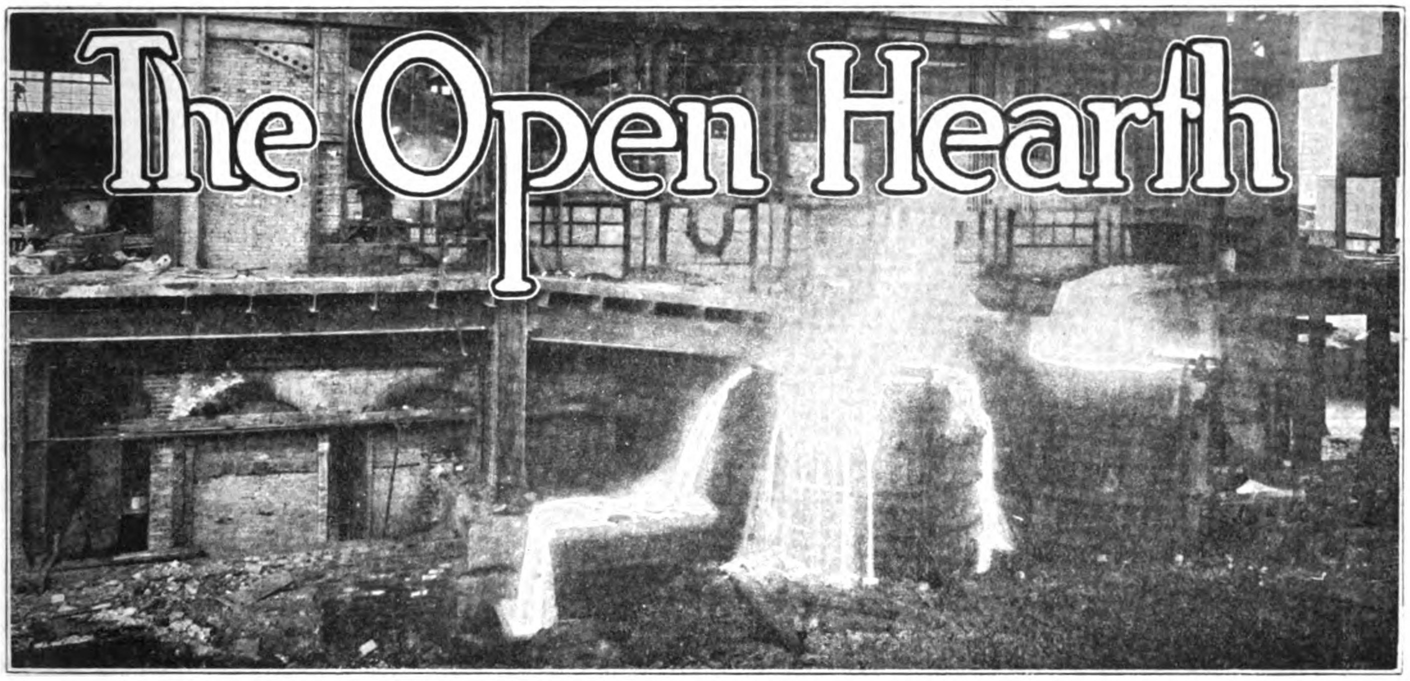
The Great Southern Steel Company, Chicago, Ill., is perfecting plans for the erection of its proposed new plant in the Birmingham, Ala., district, and will construct two new blast furnaces, with capacity of about 220 tons, at this location. Following a large steel mill will be erected, consisting of a number of buildings, all fully equipped for different branches of manufacture. The complete initial works will cost close to $1,000,000, including machinery. The company has a large tract of land in this section, including iron ore and coal properties in Etowah and other counties. The company is reported to have been negotiating for the purchase of the property of the White Iron & Coal Company, Gadsden, Ala., but with offers declined. The latter organization has engaged the Robert W. Hunt Company, Chicago, engineer, as operating manager of its local plant. The Great Southern Steel Company was organized recently under Delaware laws with a capital of $105,000,000. The board of directors will include J. S. Stearns of the Stearns & Culver Lumber Company, Ludington, Mich., and P. M. Stearns, a lumberman with closely affiliated interests; also, Judge H. W. Seaman, Chicago, and John I. Beggs, Milwaukee, Wis., identified with electric traction interests in this section. The company is represented by Charles E. Pain, attorney, First National Bank Building, Chicago.

The American Sheet & Tin Plate Company, Pittsburgh, Pa., has work under way on new pickling and galvanizing buildings at its Vandergrift plant, and will install considerable equipment for the different features of operaton. New furnaces will also be provided for the hot mills at the works.

The Tennessee Coal, Iron & Railroad Company, Birmingham, Ala., has work under way on the rebuilding of the No. 1 blast furnace at its Ensley, Ala., plant. Improvements in the power house at the plant will also be made.

The American Steel & Wire Company, Donora, Pa., is arranging for the relining of one of the furnaces at its local works, and has production under way at the other furnaces at the works, as well as the two furnaces at its Schoenberger plant.

The Republic Iron & Steel Company, Youngstown, Ohio, is increasing operations at its plant and has recently reopened two of the merchant bar mills following an extended shut down .



The Open Hearth

It was recently announced by F. J. Griffith, that he had resigned his position as vice-president and general manager of the Central Steel Co., Massillon, Ohio, but will remain with the company in his former capacity, having been reelected at a recent meeting, when the reorganization of the company was completed. The reorganized company with the consolidation of formerly affiliated units, has practically the same organization as before. R. E. Bebb is chairman and president; C. E. Stuart, secretary and treasurer; C. C. Chase, vice-president, and in charge of the sheet division; H. M. Naugle, vice-president and in charge of the metal lumber division; J. M. Schlendorf, manager of sales; B. F. Fairless, superintendent and manager of operations; Myron Phillips, manager of production; E. C. Smith, chief metallurgist, and George D. Evans, purchasing agent.

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John Stambaugh, director of the Brier Hill Steel Co., Youngstown, Ohio, leaves this week for a tour of Europe, accompanied by his wife.

√ √

At the annual meeting of the stockholders of the Inland Steel Co., Chicago, on January 31, former directors being re-elected and Gordon Battelle, Columbus, Ohio, was elected director to succeed Elias Colbert, deceased. L. E. Block and P. D. Block were re-elected chairman of the board and president respectively. Edward M. Adams was elected first vice-president to succeed G. H. Jones and W. D. Truesdale was elected secretary-treasurer. Other vice-presidents are H. C. Jones, E. J. Block, J. W. Lees, W. C. Carroll and Charles R. Robinson, the latter two having recently become affiliated with the company, as previously announced in these columns.

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On February 14th, the George Washington sailed, carrying on board Mr. Evans F. Jones, of the Morgan Construction Co., Worcester, Mass., for a 64 days' trip to the Holy Land and other points of interest.

√ √

It was announced that A. J. McFarland, general manager, Portsmouth Ohio Works, Wheeling Steel Corporation, has been transferred to the Steubenville, Ohio, works of the company and will assume the position of general manager made vacant by the resignation of G. B. LeVan. G. W. Moore, general superintendent, Portsmouth works, has been promoted to the position of general manager, vice Mr. McFarland.

√ √

Walter H. Radtke, has resigned his position as chief metallurgist of the Canton Sheet Steel Co., Canton, Ohio, which position he held for several years.

√ √

R. M. Wolvin, president of the British Empire Steel Corp., has returned to Halifax, N. S., from England and Germany, where he had gone in an endeavor to sell ore from the corporations Wabana mines.

√ √

At the recent annual meeting of the Alan Wood Iron & Steel Co., Philadelphia, Richard G. Wood was elected president of their company. Jonathan R. Jones was elected vice-president. Both Mr. Wood and Mr. Jones had occupied these positions for many years prior to 1920. Two years ago they resigned these offices and Mr. Wood retired with the title of chairman of the board and Mr. Jones as vice-president.

√ √

G. B. Wickersham, secretary-treasurer and director of the Muncie Steel Supply Co., has organized G. B. Wickersham & Co., Pittsburgh, to handle scrap and to conduct a general business as auctioneers, appraisers, and liquidators. He will continue with the Muncie Co.

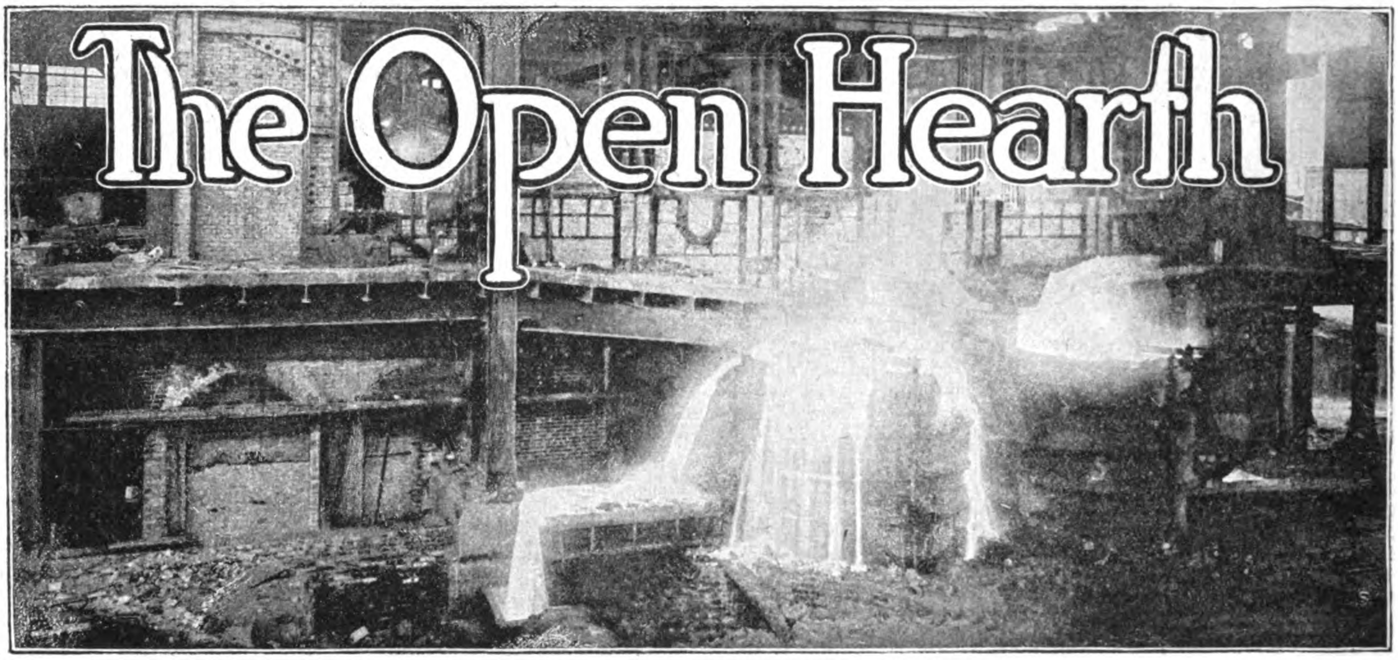
√ √

W. W. Scott, Jr., has announced his resignation as manager of sales in St. Louis for Carnegie Steel Co., the Illinois Steel Company, and the Tennessee Coal, Iron & Railroad Co., to become general manager of sales for the Laclede Steel Co., St. Louis, effective February 1, has been affiliated with one or more of the United States Steel Corporation's subsidiary companies since its formation in 1901.

√ √

Andrew H. Green, Jr., vice-president in charge of operations of the Solvay Process Co., Syracuse, N. Y., has been elected president of the Charcoal Iron Co., of America, Detroit, succeeding F. W. Blair who resigned at a meeting held January 26. Mr. Green was manager of the Solvay plant in Detroit up to two years ago, when he was transferred to the headquarters of the company. He was active in civic affairs at Detroit and was decorated by the French government for his services during the world war.

The Open Hearth



Eric A. Lof, of the power and mining department of the General Electric Co., Schenectady, has had the Royal Order of Vasa conferred upon him by the King of Sweden in recognition of meritorius services rendered his government. The decoration is similar to those of the legion of honor in France. Mr. Lof spent several months in Europe last year for the International General Electric Co., partly in connection with the extensive power transmission and railway electrification projects which are being planned by the Swedish government.

V V

Charles Russ Richards, dean of engineering and director of the experimental engineering department of the University of Illinois, has been elected president of the Lehigh university. He succeeds Dr. Henry S. Drinker, now president emeritus at Lehigh. Mr. Richards is a graduate of Purdue University and a post-graduate of Cornell.

V V

C. C. Boyden who has in the past been identified with various pig iron interests in the East and who for the past four months has been on the Pacific coast, has returned and is temporarily at Foxboro, Mass.

V V

Joseph W. Powell, president of the Emergency Fleet corporation is to resume his former position as head of the Fore River Works, Quincy, Mass., of the Bethlehem Shipbuilding Corp., Ltd., when he retires March 4.

V V

Louis F. Vonier, formerly manager of the Milwaukee office of the Federal Bridge & Structural Co., Waukesha, Wis., has become associated with the Central Steel Co., Massillon, O., as district representative of its National Pressed Steel Division in the Wisconsin territory. Mr. Vonier has opened new offices at 412 Matthews Building, Milwaukee.

V V

W. Wallace McKaig recently succeeded W. J. Muncaster as vice-president and general manager of the Cumberland Steel Co., Cumberland, Md. Mr. Lancaster has retired. J. F. Stark was elected secretary and treasurer of this company to succeed Albert Charles, who remains a director of the company. Merwin McKaig is president of the company.

V V

William J. Morris, for many years assistant treasurer Youngstown Sheet & Tube Co., Youngstown, Ohio, has been elected treasurer, succeeding Richard Garlick, resigned because of ill health. Mr. Garlick has been treasurer virtually since the formation of the company in 1900. He continues on the board of directors. For the past few years Mr. Morris has been practically acting treasurer. Walter E. Meub, secretary of the company and assistant to President James A. Campbell, was elected assistant treasurer, Mr. Garlick is now in the south with his family.

V V

Robert A. McDonald, for a number of years manager, Crescent Works, Crucible Steel Company of America, Pittsburgh, has been promoted to the position of general superintendent of all plants of the company with headquarters in New York.

V V

Albert H. Whipple, superintendent of the Whitin Machine Works, Whitinsville, Mass., recently received a 50-year service pin from the company. Mr. Whipple entered the employ of the Whitin company in January, 1872, as an apprentice and has had an unbroken service record ever since.

V V

Frederick K. Vial, chief engineer Griffin Wheel Co., Chicago, and consulting engineer for the Association of Manufacturers of Chilled Car Wheels, will represent the last named organization at the convention of the International Railway Association at Milan, Italy, April 18 to 30. This will be the first meeting of the International Association to be held since 1910. This body ordinarily convenes every five years, but the last meeting, which was scheduled to take place at Berlin in 1915, was abandoned for obvious reasons.

V V

James E. McKenny, for the past year superintendent of the Standard Spring Co., Cleveland, has resigned and returned to his former home in Worcester, Mass. Before going to Cleveland he was located in Youngstown, O. Mr. McKenny is a former superintendent of the National works of the Wickwire Spencer Steel Corp., Worcester, and at one time was production manager for the former Morgan Spring Co. of that city, now the oMrgan works of the Wickwire Spencer Steel Corp.

V V

James B. Taylor has been elected a director of the American Can Co., succeeding the late Henry R. Hoyt.

Some Pointers on By-Product Coke Oven Operations

REVIEW OF COKING IN THE PACIFIC NORTHWEST.

The coking industry of the Pacific Northwest during 1921 has reflected the general industrial depression common to the country at large. In addition, a strike of coal miners, which began in March and which is still in force in most of the commercial mines in Washington, cut off the production of coal in the principal coke producing county in the state.

Practically all of the coke produced in Washington, which is the only state west of the Rockies manufacturing coke, comes from an area closely tributary to Seattle and Tacoma. Tacoma is the county seat of Pierce county, which contains the principal deposits of coking coal and is the leading producer of beehive coke. The total number of beehive ovens in the state is 494; of these, 409 are in Pierce county, the remainder are in King and Skagit counties, not far from Seattle. The Seattle Lighting Company has a battery of 5 by-product ovens of the Klonne type made by the National Chamber Oven Company consisting of 20 chambers. This plant operates primarily to produce illuminating gas for the city of Seattle, but its coke is used for domestic, industrial, and, to a lesser degree, for metallurgical purposes. All of the beehive coke is sold for foundry and smelter use.

Much Coal of Fine Sizes is Produced Which Necessitates Washing.

In normal times all of the coke produced is made from washed coal. The seams producing coking coal are badly folded and stand at high angles, making mining difficult and causing large percentages of fine sizes. Admixture of foreign material, both from the seams and from the enclosing walls, make washing necessary. Jigging has been the customary practice, but, recently, considerable attention has been given to the preparation of fine sizes on concentrating tables, with very encouraging results. The ash content of Washington coke is rather higher than in other localities because of the nature of the coal and the difficulty in economically receiving the intimately mixed ash-bearing constituents. On the other hand, sulphur and phosphorus are low.

The great bulk of the beehive product is 48-hour coke, although 72-hour and 96-hour coke are also produced. The former is almost entirely used in nonferrous smelting; the latter in foundry use. The by-product coke made at Seattle is a 24-hour product.

Market For the Product and Recent Production Figures.

The market, in the past, has extended from California to Alaska. The coast district of British Columbia, until the establishment of the by-product plant at Anyox, absorbed a considerable portion of the production. The copper smelter at Tacoma took a large bulk of the production, but the closing down of the blast furnaces in favor of reverberatory smelting eliminated a large market. The blast furnaces, however, are being put into service again and there is a revival of the market for Pierce county coke.

It is estimated that the plants in the state have a potential or possible production of 300,000 tons annually. This production has, however, never been reached. The banner year was in 1915 when 136,522 tons were produced. The 1920 production was 69,282 tons, made up of 42,998 tons from the beehive ovens and 26,284 tons from the by-product ovens. Production figures for the past few years are indicated below:

Year.	Coke Produced* (Short Tons)	Total Value of Coke at Ovens.	Value of Coke at Ovens Per Ton.	Yield of Coal in Coke (%)
1915	136,552	$ 700,832	$5.13	66.7
1916	125,872	662,987	5.27	61.5
1917	122,758	906,318	7.38	59.7
1918	123,788	1,092,741	8.18	60.6
1919	65,332	565,356	8.65	63.4
1920	69,282	361,582	5.22	60.5
1921	3,600–			

* Includes by-product coke.
– Eleven months only.

The production of by-product coke is shown by the following figures:

Year.	Coke Produced* (Short Tons)	Value of Coke.
1914	6,751	$ 36,585.66
1915	30,182	158,472.17
1916	29,516	159,321.69
1917	27,635	210,857.81
1918	26,260	233,815.01
1919	26,955	207,116.23
1920	26,284	162,309.92
1921–	22,257	154,136.91

* Does not include breeze.
– Eleven months only.

The total 1921 production will be the lowest in many years. The output of by-product coke has been fairly steady because of the fact that the plant is primarily operated for gas. The production up to December first is 22,257 tons, valued at $154,136.91. The average value has been $6.925 per ton.

The beehive production this year has practically all come from the ovens of the Wilkeson Coal & Coke Company. A small quantity of 72-hour coke for foundry purposes, amounting to 1,272 tons, was produced during the first three months of the year at Wilkeson, and some 700 tons is reported to have been produced by the Western Coke and Collieries Co., at Snoqualmie. Resumption of blast furnace copper smelting at the Tacoma Smelter, a subsidiary of the American Smelters Securities Co., has revived the production of 48-hour coke during the past three months. The total production of beehive coke for 1921 is estimated to be 4,200 short tons. The average value of this coke at the ovens is approximately $8.00 per ton.

The grand total for the state for 1921 is estimated to be 30,000 tons valued at approximately $210,000.

The Coast district of British Columbia has two coking establishments,—one, a beehive plant at Union Bay, owned by the Canadian Collieries (Dunsmuir) Lt., consisting of 200 ovens; the other a by-product plant, erected in 1918, by the Granby Consolidated Mining, Smelting and Power Co., at Anyox, which consists of a battery of 30 ovens made by the Gas and Coke Company of America.

The reported figures of production for the Anyox plant in 1910 are as follows: Coke 77,290 short tons; breeze, 2,896 tons; tar, 757,057 imperial gallons; sulphate of ammonia 2,465,995 pounds; benzol, 121,734 gallons; gas, 1,203,954 cubic feet. No definite figures for 1921 are yet available, but it is believed that the coke production for this year will be equal to that of 1920.

TRADE NOTES

The Homestead Sales Corporation, 242 Lafayette Street, New York City, has been appointed sole agent for New York and vicinity by the General Specialty Company of Buffalo, N. Y., in the sale of their Torpedo Tube Cleaner and other boiler cleaning specialties.

The Orton & Steinbrenner Co. of Chicago, manufactures locomotive cranes, clam shell and orange peel buckets, have made arrangements with the F. C. Richmond Machinery Co., 117 West Second Street, Salt Lake City, Utah, to represent them.

The Philadelphia office of the Hauck Manufacturing Company, manufacturers of portable oil burners, torches, furnaces, etc., has been moved to 1726 Sansom Street. Bell 'Phone, Spruce 5626.

Stone & Webster, Inc., of Boston, have awarded a contract to The U. G. I. Contracting Company, of Philadelphia, for the installation of two 11' sets of carburetted water gas apparatus at the plant of the Fall River (Mass.) Gas Works Company. These sets will be of the U. G. I. cone top type, hydraulically equipped and will have the other modern appurtenances usual to U. G. I. apparatus.

The Rathbun Jones Engineering Company, Toledo, Ohio, has appointed the Ingersoll-Rand Company, New York, General Sales Agent for Rathbun Gas Engines. The large sales organization and service department of the Ingersoll-Rand Company, combined with the fact that gas engines are used to drive compressors, pumps and other machinery which it manufactures, places it in a position to serve better the users of gas engines and other machinery.

The Skinner Engine Co. of Erie Pa. has appointed Andrews-Bradshaw Co., 812 B. F. Jones Building, Pittsburgh, Pa., as their representatives in the Pittsburgh district.

The Koppers Company has been awarded a contract for a "Koppers Liquid Purification Plant" by the Battle Creek Gas Company of Battle Creek, Michigan. This plant will have a daily capacity for handling 2,000,000 feet of gas per day. A plant of this type has been in operation for over a year at Seaboard By-Product Coke Company's Plant at Jersey City, N. J., handling the entire gas output of that company, amounting to over 25,000,000 feet of gas per day. This method of gas purification has aroused a great deal of interest in the gas industry and was fully described in a paper read before the last meeting of the American Gas Association in Chicago.

The George J. Hagan Company have recently opened up offices in Detroit and Chicago. The Detroit office is located at 515 Murphy Building and is under the management of Mr. J. Sandberg, formerly of the General Electric Co. The Chicago office is located at 20 E. Jackson Boulevard and is under the management of Mr. V. A. Hain, formerly of the General Electric Co.

The Hardinge Company announces the acquirement of the Coal Washing Equipment as formerly supplied by the Coal Washing Equipment Co. of Pottsville, Pa. The equipment consists mainly of the James Automatic Balanced Jig, a device which has been developed and installed in a number of anthracite and bituminous collieries for reducing the sulphur and non-combustible content of coals ranging in sizes from ¼ in. to 4 in.

The Wilson Welder & Metals Company, Inc., 132 King Street, New York, N. Y., manufacturers of Arc Welding Machines and Certified Welding Metals announces the appointment of Mr. R. L. White as District Manager in charge of Detroit Office, 809 Kresge Building, Detroit, Michigan.

The Bario Metals Corporation of New York City will commence at once the installation of a new Alloy Melting Department including the installation of Four (4) Electric Melting Furnaces. The contract for the complete melting department has been awarded to F. J. Ryan & Company (Industrial Furnace Engineers), Wesley Building, Philadelphia, Pa.

Mr. C. L. Dewey, who was associated with Mr. Carl Akeley in the invention and development of the Cement-Gun, and who has done extensive Cement-Gun contract work under the names of the Dewey Cement-Gun Company and the Traylor-Dewey Contracting Co. of Allentown, Pa., has joined the forces of the Cement-Gun Construction Co. of Chicago, Ill.

TRADE PUBLICATIONS

The Treadwell Engineering Company of Easton, Pa., have issued a new catalogue illustrating and describing their "Stoever" line of Pipe Machines. These machines are used for cutting and threading steel and wrought iron pipe. For those engaged in this sort of work, this catalogue will prove very interesting.

The Deschanel Engineering Corporation of New York have just issued "Deschanel Cableway Bulletin," which describes their single line cable way used for material handling purposes. It will be sent upon request.

The Alabama Company, Birmingham, have issued an attractive booklet in reference to their machine cast pig iron. This method of handling pig iron is new in the south; this company being the only one to produce foundry iron in this way.

The Blaw Knox Company have issued a circular on Knox Patented Damper Type Water Cooled Reversing Valves. Many of these valves are now in use in the steel plants.

The Uehling Instrument Company of New York have recently issued two bulletins which they say are the beginning of a series on Combustion and the Cost of Power. The first, No. 220, is entitled "Magnitude of the Power Plant's Chimney Loss" and considers the importance of the loss through excess air. An interesting diagram is given showing the relative amounts of CO_2, excess air, and heat loss. It emphasizes the importance of apparatus for indicating and recording this condition. No. 221 is entitled "Relation Between CO_2 and Money Wasted up the Chimney." It contains a number of interesting tables and diagrams illustrating the money to be saved by increasing the percentage of CO_2 in the flue gas.

A new recording thermometer is described in an 8-page folder recently issued by the American Steam Gauge & Valve Mfg. Co. of Boston, Mass. This recorder is actuated by different methods, saturated vapor expansion, inert gas, or other liquids, depending on the purpose for which it is to be used.

"Water Tube Boilers" is the title of a new catalog recently issued by the Springfield Boiler Co., Springfield, Ill. It describes the equipment manufactured by this company and the advantages of it. The catalog is very well printed and shows to good advantage the numerous illustrations of the Springfield boiler applied to furnaces, both in the form of halftones and line cuts of blue prints. 24 pages and cover, size 8½x11.

The Mines Branch of the Canadian Department of Mines has recently published their Bulletin No. 564 on the "Preparation, Transportation, and Combustion of Powdered Coal" by John Blizard. This considers the various phases of the subject, the makes of equipment available, the results which have been obtained.

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THE JOHN CRERAR
MAR 15 1922

Member of the Audit Bureau of Circulations.

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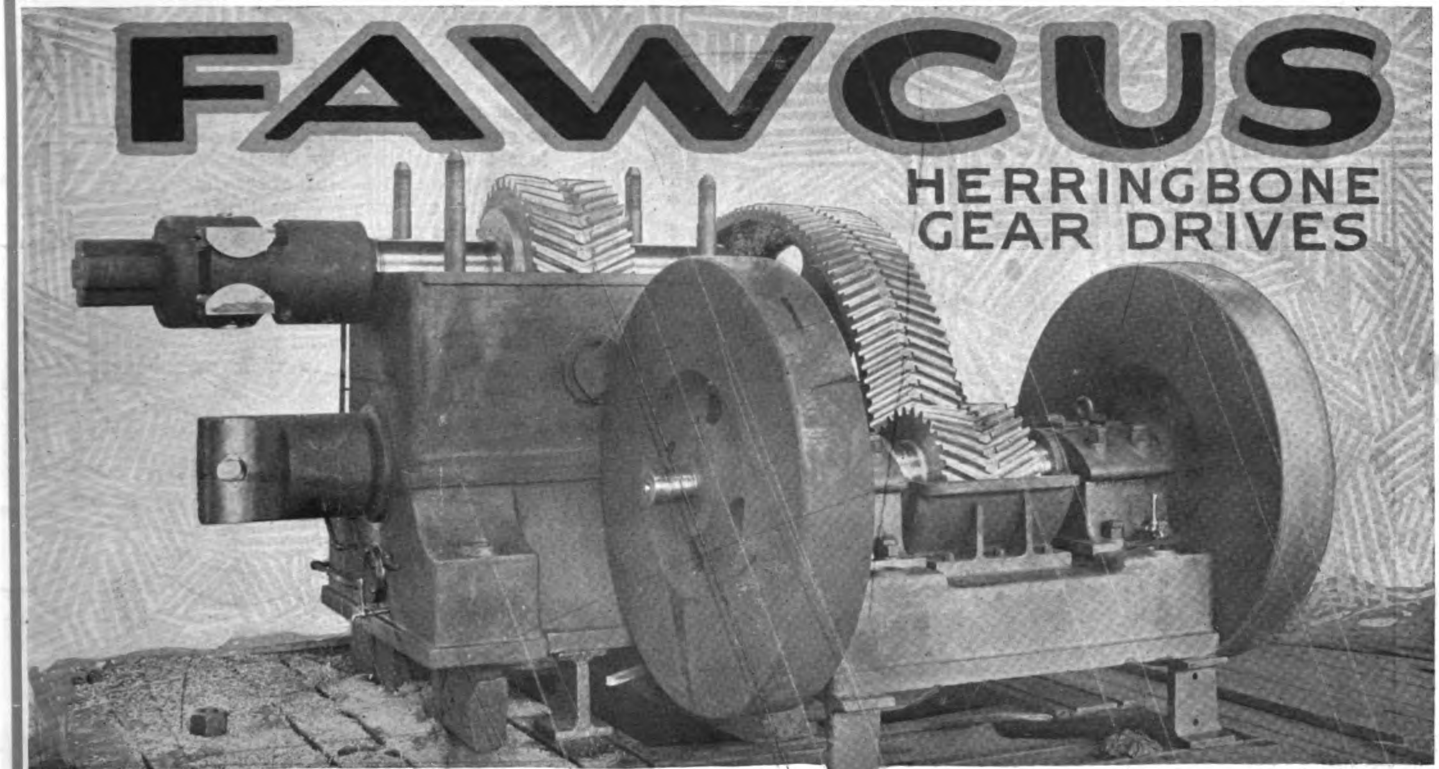
The Blast Furnace and Steel Plant

Pittsburgh, March, 1922.

FAWCUS
HERRINGBONE
GEAR DRIVES



Fawcus Combination Herringbone Gear Reduction and Pinion Housing

FAWCUS Drive recent development (Patents pending). This design confines transmission of power from motors to mills in a single unit, practically eliminating vibration, and as a result wear, tear, and maintenance are reduced to an absolute minimum. In addition to saving considerable space over separate pinion housing and reduction gear also with first cost considerably less.

FAWCUS Standard and Special Herringbone Gear Reductions for transmitting maximum loads up to and including 15,000 H.P. built to meet the severe requirements of Rolling Mill Services.

FAWCUS MACHINE CO., PITTSBURGH, PA.

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BIRMINGHAM, ALA.—G. R. Mueller Co.
NEW YORK, N. Y.—R. C. Brown, 84 Pine St.
MILWAUKEE, WIS.—L. E. Meidinger.
PORTLAND, ORE.—Coast Steel Machinery Co.
SAN FRANCISCO, CALIF.—K. W. Eichelberger.